



# ANSI/ASHRAE/IESNA Standard 90.1-2007

## U.S. Department of Energy Building Energy Codes Program





# Why is Standard 90.1-2007 Important?

- It replaces ANSI/ASHRAE/IESNA Standard 90.1-2004
- It will be the reference standard for the 2009 IECC
- It is the professional “standard of care” set by ASHRAE consensus



# ✓ How Can I Get a Copy?

- Standard 90.1-2007 and the Standard 90.1-2007 User's Manual are available from ASHRAE



[www.ashrae.org](http://www.ashrae.org)



404-636-8400



# Standard 90.1-2007

- Section 1 - Purpose
- Section 2 - Scope
- Section 3 - Definitions, Abbreviations, and Acronyms
- Section 4 - Administration and Enforcement
- Section 5 - Building Envelope
- Section 6 - Heating, Ventilating, and Air Conditioning



# ✓ Standard 90.1-2007

- Section 7 - Service Water Heating
- Section 8 - Power
- Section 9 - Lighting
- Section 10 - Other Equipment
- Section 11 - Energy Cost Budget Method
- Section 12 - Normative References



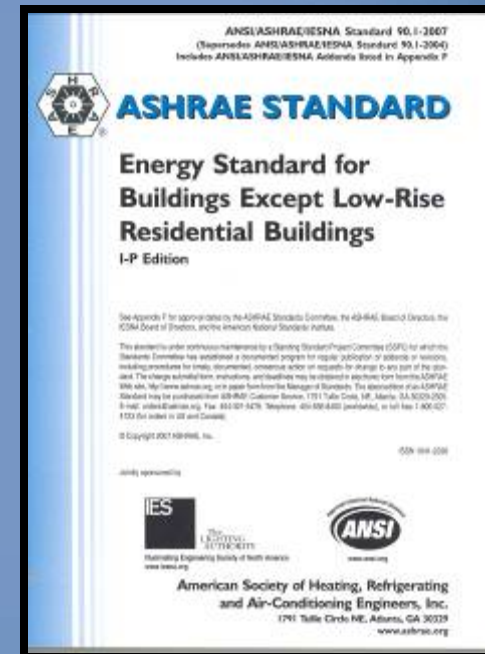
# ✓ Standard 90.1-2007 Appendices

- **A** – Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations
- **B** – Building Envelope Climate Criteria
- **C** – Methodology for Building Envelope Trade-Off Option in Subsection 5.6
- **D** – Climatic Data
- **E** – Informative References
- **F** – Addenda Description Information (Informative)
- **G** – Performance Rating Method (Informative)



# ✓ Section 1 - Purpose

To provide minimum requirements for the energy-efficient design of buildings except low-rise residential buildings



## ✓ Section 2 - Scope

- New buildings and their systems
- New *portions* of buildings and their systems (additions)
- New systems and equipment in *existing* buildings (alterations)





## Section 2 – Scope *(cont'd)*

- Envelope
  - if heated by a heating system with an output capacity  $\geq 3.4$  Btu/h-ft<sup>2</sup> or
  - if cooled by a cooling system with a sensible output capacity  $\geq 5$  Btu/h-ft<sup>2</sup>
- Virtually all mechanical, power, and lighting systems are covered



# ✓ Scope Exceptions

- Too little heating or cooling
- Single-family, multifamily of three stories or less, manufactured or modular homes
- Buildings that don't use electricity or fossil fuel
- Equipment and portions of building systems that use energy primarily for industrial, manufacturing, or commercial processes



# ✓ Section 3 - Definitions, Abbreviations, and Acronyms

- 10 pages of definitions
- 1 page of abbreviations and acronyms
- Defined terms are italicized in text of standard





## Section 4 – Administration and Enforcement

- New buildings, additions to existing buildings, and alterations to existing buildings
- Replacement of portions of existing buildings
- Changes in space conditioning





## Section 4 – Administration and Enforcement

- Compliance documentation
- Labeling of materials and equipment
  - Fenestration, doors, insulation, mechanical equipment, and packaged terminal air conditioners
- Alternative materials and methods of construction
- Inspections





## Section 4 – Administration and Enforcement

- Section 4 merely provides the overall statement that new buildings, additions, alterations, replacements, and changes in space conditioning fall under the requirements of the Standard
- Details of which requirements the building must actually meet in various situations are discussed in the technical sections 5, 6, 7, 8, 9, 10, and 11 in the X.1 section named “General”



# ✓ Section 4 – Exceptions for Alterations

- Buildings that are specifically designated as historic
  - by the adopting authority or
  - on the National Register of Historic Places or
  - eligible for listing by the U.S. Secretary of Interior
- If the the building's annual energy consumption is the same as a building that meets the requirements of Sections 5-10
  - verified by a design professional using methods acceptable to the authority having jurisdiction

# ✓ Compliance Approaches

## Building System

Envelope

HVAC

SWH

Power

Lighting

Other

## Compliance Options

Prescriptive  
Option

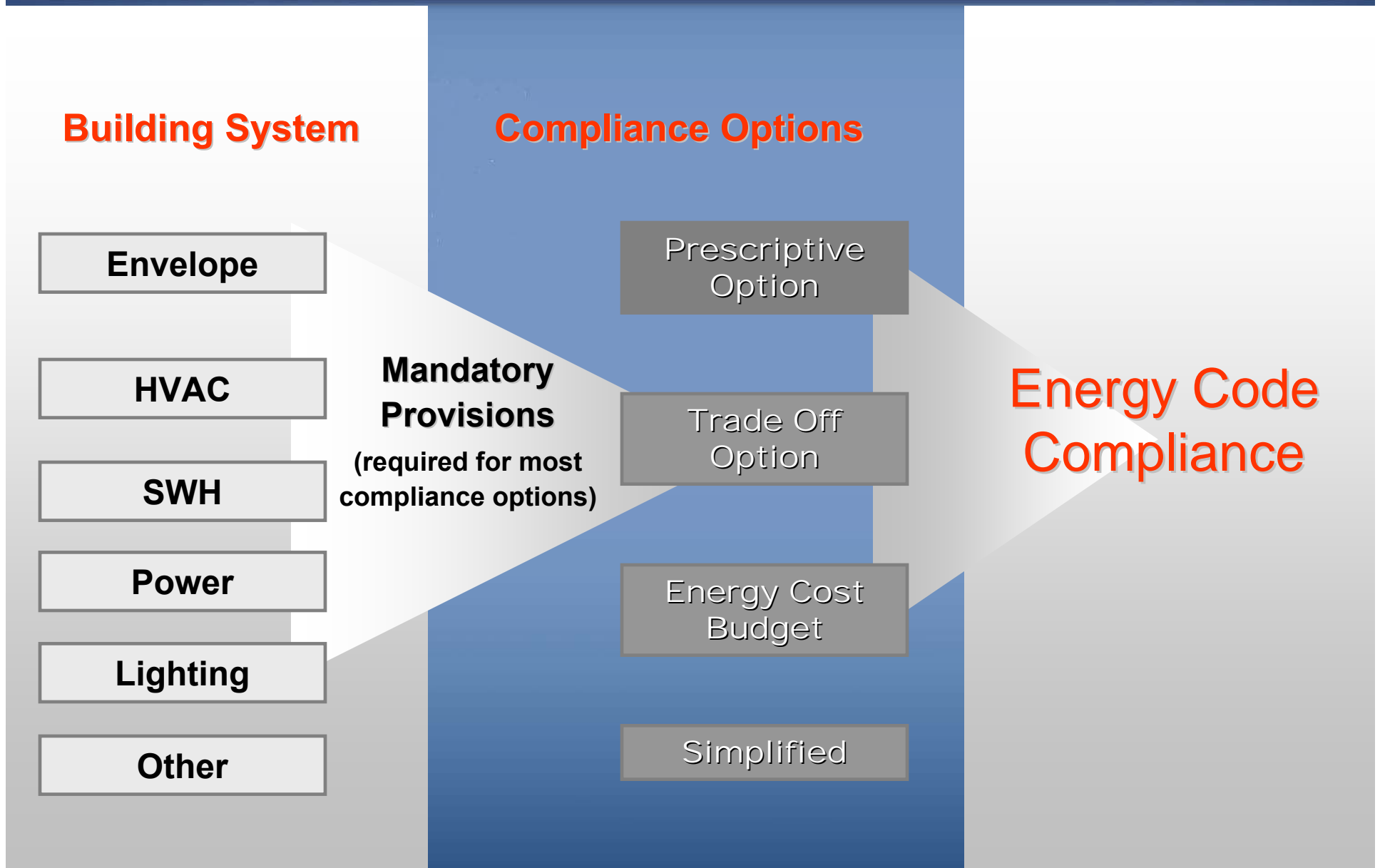
Trade Off  
Option

Energy Cost  
Budget

Simplified

**Mandatory Provisions**  
(required for most compliance options)

## Energy Code Compliance





# Envelope Compliance

## Building System

## Compliance Options

Envelope

Prescriptive  
Option

HVAC

**Mandatory  
Provisions**  
(required for most  
compliance options)

Trade Off  
Option

SWH

Power

Energy Cost  
Budget

Lighting

Other

Simplified

## Energy Code Compliance

# ✓ Section 5 – Building Envelope

- General (*Section 5.1*)
  - Scope
  - Space-Conditioning Categories
  - Envelope Alterations
  - Climate
- Compliance Methods (*Section 5.2*)
- Simplified Building (*Section 5.3*) Not Used
- Mandatory Provisions (*Section 5.4*)
  - Insulation
  - Fenestration and Doors
  - Air Leakage



# ✓ Section 5 – Building Envelope *(cont'd)*

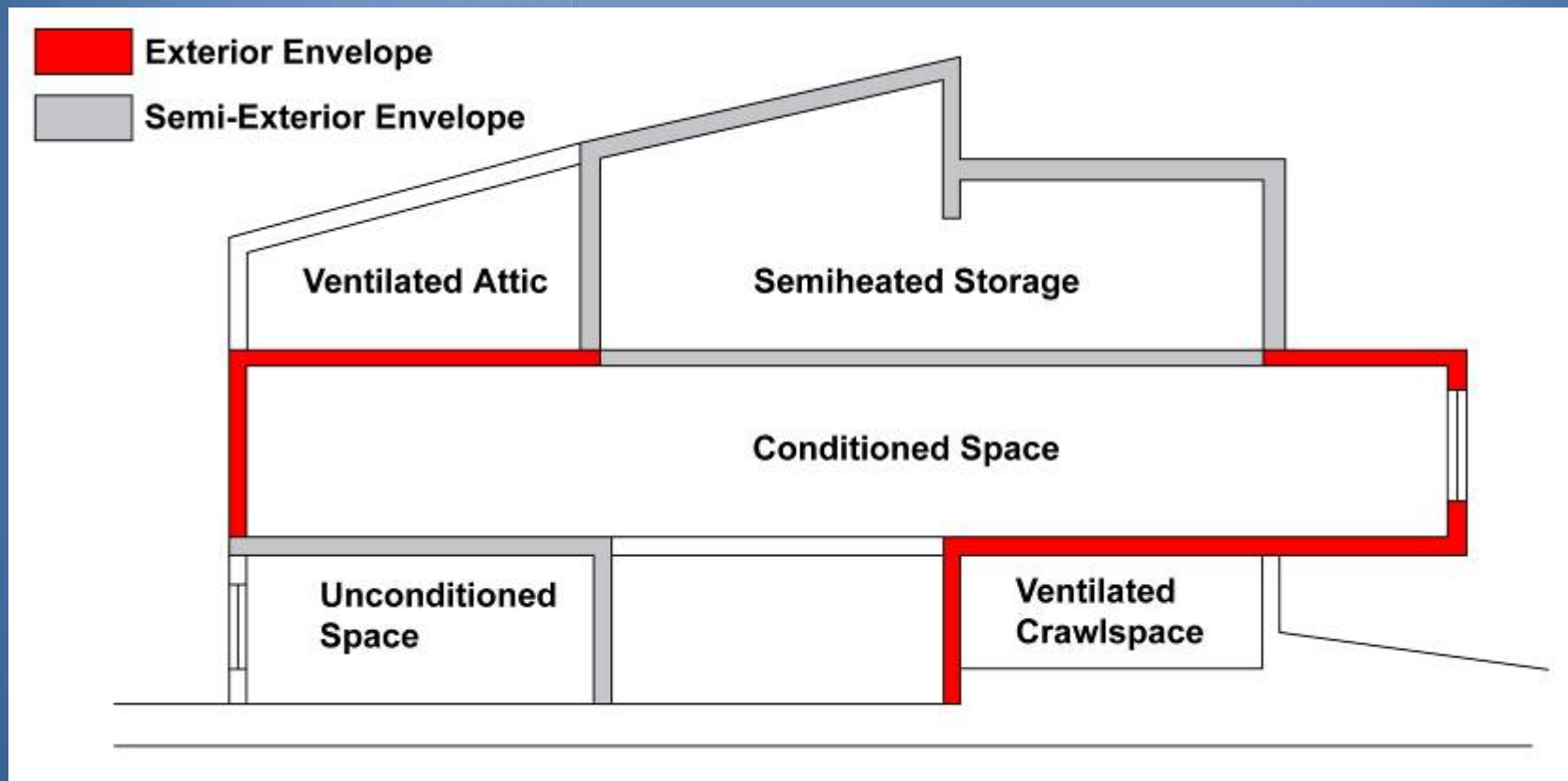
- Prescriptive Building Envelope Option (*Section 5.5*)
  - Opaque Areas
  - Fenestration
- Building Envelope Trade-Off Option (*Section 5.6*)
- Submittals (*Section 5.7*)
- Product Information and Installation Requirements (*Section 5.8*)



- Envelope components that enclose
  - Conditioned space
  - Semiheated space
    - Has a heating system with a capacity  $> 3.4 \text{ Btu/h}\cdot\text{ft}^2$  of floor area but is not conditioned space
- Requirements apply to three types of spaces
  - Nonresidential
  - Residential
  - Semiheated
- Exceptions



# Building Envelope



# ✓ Space-Conditioning Categories and Basis

*Envelope Requirements Are Specified by Space-Conditioning Categories*

- Each space to be included in a category
  - Nonresidential conditioned space
  - Residential conditioned space
  - Semiheated space
- Spaces in climate zones 3-8 assumed to be conditioned space unless
  - Space will only be semiheated or unconditioned and
  - Approved as such by the building official



# ✓ Semiheated Space

- Has a heating system with a capacity  $> 3.4 \text{ Btu/h.ft}^2$  ( $10 \text{ W/m}^2$ ) of floor area but is not conditioned space
- Space is not cooled at all



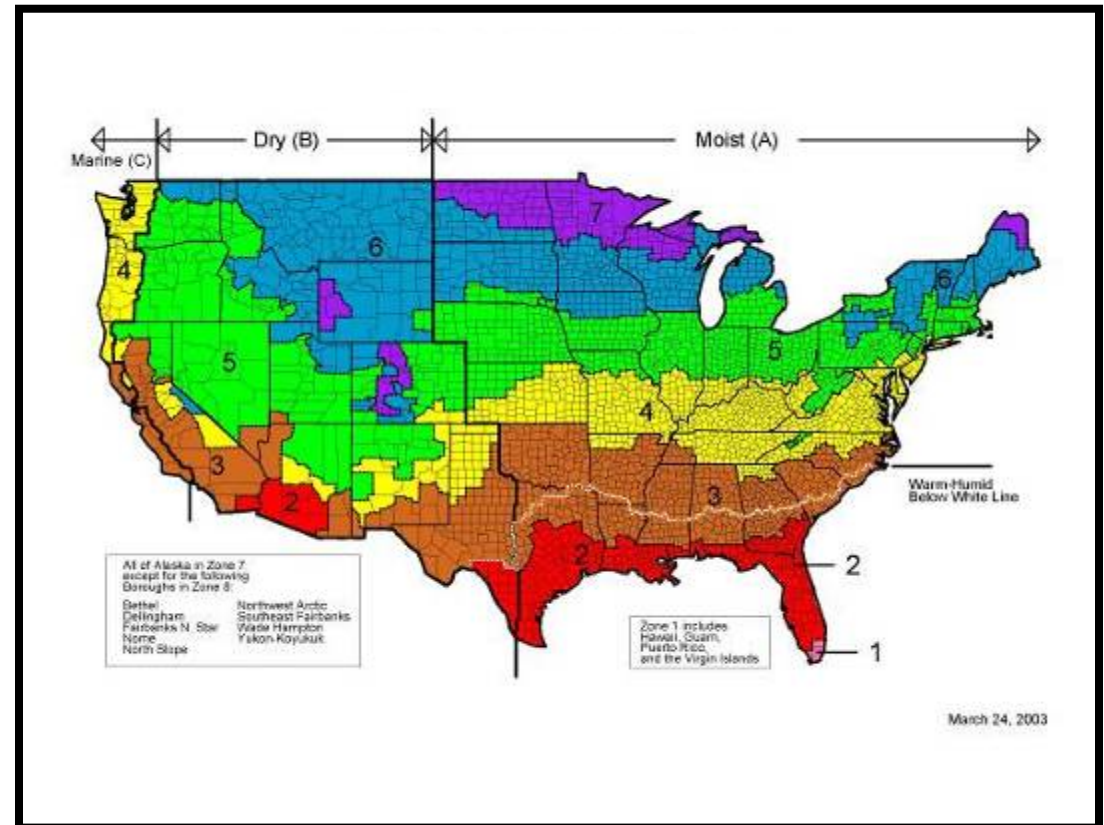
# ✓ Envelope Alterations

- Alterations to the building envelope shall comply with the requirements of Section 5
  - Exceptions that are allowed if they don't increase energy usage of building
    - Installation of storm windows
    - Replacement of glazing in existing sash and frame
    - Alterations to envelope cavities provided they are insulated to full depth with a nominal R-3.0 per in.
    - Roof and floor alterations where no new cavities are created
    - Replacement of roof membranes
    - Replacement of existing doors
    - Replacement of existing fenestration, provided area of replacement is no more than 25% of total fenestration area





- Zones based on several climatic parameters
  - Locations listed in Appendix B on county-by-county basis for United States





# Envelope Compliance Paths

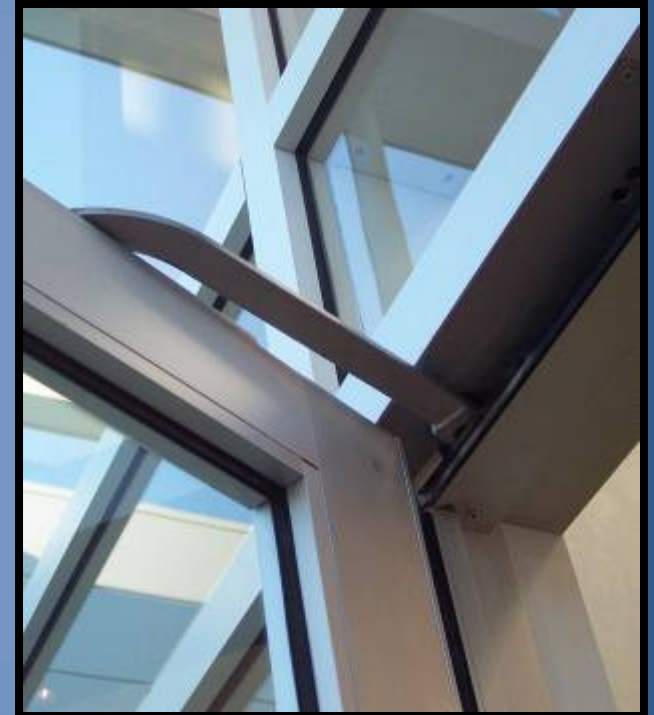
- Section 5.2
- You have to follow Sections
  - 5.1 (General),
  - 5.4 (Mandatory Provisions),
  - 5.7 (Submittals), and
  - 5.8 (Product Information and Installation Requirements),
- and THEN you can either follow
  - Section 5.5 (Prescriptive) or Section 5.6 (Trade-off)
- Alternatively, you can follow Section 11 (ECB), in which case Section 5.4 is mandatory
  - However, Section 5.4 merely refers to Section 5.8





# Mandatory Provisions

- Insulation (*Section 5.8.1*)
  - Labeling (*Section 5.8.1.1*)
  - Substantial Contact (*Section 5.8.1.5*)
  - Recessed Equipment (*Section 5.8.1.6*)
  - Insulation Protection (*Section 5.8.1.7*)
  - Insulation Above Suspended Ceilings (*Section 5.8.1.8*)
- Fenestration and Doors (*Section 5.8.2*)
- Air Leakage (*Section 5.4.3*)



# ✓ Air Leakage

- Seal, caulk, gasket, or weather-strip
  - Openings and joints in building envelope
  - Fenestration and doors per NFRC 400
  - Loading docks in climate zones 4-8
  - Vestibules and doors separating conditioned space from exterior



# ✓ Air Leakage - Building Envelope Sealing

- Joints around fenestration and door frames
- Junctions between walls
  - and foundations
  - at building corners
  - and structural floors or roofs
  - and roof or wall panels
- Openings for utility services through roofs, walls, and floors
- Site-built fenestration and doors
- Building assemblies used as ducts or plenums
- Joints, seams, and penetrations of vapor retarders
- All other openings in the building envelope



# Air Leakage - Fenestration and Doors

- NFRC 400
- Labeled and certified by manufacturer
- Glazed swinging entrance doors and revolving doors – not to exceed 1.0 cfm/ft<sup>2</sup>
- All other products – not to exceed 0.4 cfm/ft<sup>2</sup>
- Exceptions
  - Field-fabricated fenestration and doors
  - Garage doors – ANSI/DASMA 105

 National Fenestration Rating Council <b>CERTIFIED</b>	<b>World's Best Window Co.</b> Millennium 2000+ Vinyl-Clad Wood Frame Double Glazing - Argon Fill - Low E Product Type: Vertical Slider
ENERGY PERFORMANCE RATINGS	
U-Factor (U.S./I-P)	Solar Heat Gain Coefficient
<b>0.35</b>	<b>0.32</b>
ADDITIONAL PERFORMANCE RATINGS	
Visible Transmittance	Air Leakage (U.S./I-P)
<b>0.51</b>	<b>0.2</b>
Condensation Resistance	_____
<b>51</b>	
<small>Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. Consult manufacturer's literature for other product performance information. <a href="http://www.nfrc.org">www.nfrc.org</a></small>	

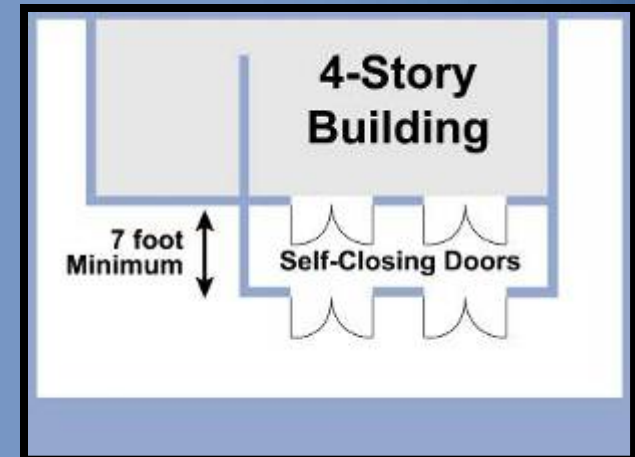
# ✓ Air Leakage - Loading Dock Weatherseals

- In climate zones 4-8
  - Cargo doors and loading dock doors equipped with weatherseals
    - To restrict infiltration when vehicles are parked in the doorway



# ✓ Air Leakage - Vestibules

- Required in
  - Climate Zones 3-4 for entrances in >4 story buildings > 10,000 ft<sup>2</sup>
  - Climate Zones 5-8 for entrances in buildings > 1000 ft<sup>2</sup>
- Vestibules must have:
  - Self-closing doors
  - Interior and exterior doors not open at the same time
  - Distance between interior and exterior doors not < 7 ft when in closed position (remember ADA!)





# ✓ Air Leakage - Vestibule Exceptions

- Non-entrance doors
- Building entrances with revolving doors
- All building entrances **in climate zones 1 and 2** OR in buildings < 4 stories and < 10,000 ft<sup>2</sup> **in climate zones 3 and 4** OR in buildings < 1000 ft<sup>2</sup> **in climate zones 5-8**
- All doors that open from spaces < 3000 ft<sup>2</sup> (separate from building entrance) OR from dwelling units



# ✓ Prescriptive Building Envelope Option

**WWR  $\leq$  40% of gross wall area**  
**Skylight-roof ratio  $\leq$  5% of roof area**  
**Each envelope component must separately meet requirements**

- 8 criteria sets for different climate types
  - Set = single page that summarizes all prescriptive requirements
    - Insulation levels for roofs, walls, floors
    - Fenestration criteria



# ✓ Designers

- Specify
  - R-values for walls, floors, and roofs
  - U-factors for opaque doors
  - U-factor and SHGC for fenestration, OR
- Use
  - Pre-calculated assemblies from Appendix A



# ✓ Opaque Areas

- Compliance
  - Meet or exceed minimum R-values in table
    - Only R-value of insulation, not to include air films, etc
  - OR
  - Meet maximum U-factor, C-factor, or F-factor for the entire assembly
  - OR
  - Perform area-weighted average U-factor, C-factor, or F-factor
    - Only if there are multiple assemblies within a single class of construction for a single space-conditioning category

# ✓ Roof Insulation

- Meet or exceed minimum R-value in table for climate zone
- Skylight curbs insulated to level of roofs with insulation entirely above deck or R-5, whichever is less
- Three types of roofs are defined:
  - Roofs with insulation entirely above deck
    - R-value is for continuous insulation
    - Interruptions for mechanical equipment  $\leq 1\%$  of surface of the total roof area



# ✓ Roof Insulation *(cont'd)*

- Metal building roofs
  - First value is for insulation
    - draped over purlins and then compressed when metal spanning members attached or
    - hung between purlins provided there's a min. of 1" thermal break between purlins and metal spanning members
  - Second value is for double-layer installations with insulation installed parallel to the purlins
- Attics and other roofs
  - R-value is for insulation installed both inside and outside the roof or entirely inside the roof cavity

# ✓ High Albedo Roofs

- Roofs with a minimum total solar reflectance of 0.70 and a minimum thermal emittance of 0.75 or a minimum Solar Reflective Index of 82, other than roofs with ventilated attics or roofs of semiheated spaces or roofs over conditioned spaces that are not cooled spaces shall comply with the values in Table 5.5.3.1.

Basically, “cool roofs” are allowed to have less insulation.

# ✓ Above-Grade Wall Insulation

- Meet or exceed R-value in appropriate table for climate zone
- Four types of walls are defined:
  - **Mass walls**
    - heat capacity determined from Table A3.1B or A3.1C
    - R-value is for continuous insulation or when uninterrupted by framing other than metal clips no closer than 24 in. o.c. horizontally and 16 in. o.c. vertically
  - Exception – requirement of U-0.151







# Above-Grade Wall Insulation *(cont'd)*

- **Metal building wall** R-value
  - for insulation compressed between metal wall panels and the steel structure
- **Steel-framed wall** R-value
  - for uncompressed insulation installed in the cavity between steel studs
- **Wood-framed and other** R-value
  - for uncompressed insulation installed in the cavity between wood studs; also acceptable to be continuous insulation uninterrupted by studs



# ✓ Below-Grade Wall Insulation

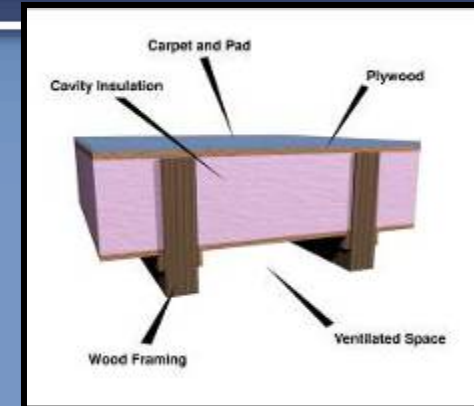
- Meet or exceed values in appropriate table for climate zone
- R-value is for continuous insulation
- If framing is used, compliance is based on maximum assembly C-factor





# Floor Insulation

- Meet or exceed values in appropriate table for climate zone
- 3 classes of floors over unconditioned space are defined:
  - Mass floors
    - R-value is for continuous insulation
    - If framing is used, compliance is based on maximum assembly U-factor
  - Steel-joint floors
    - R-value is for uncompressed insulation or spray-on insulation, but is also acceptable for continuous insulation
  - Wood-framed and others
    - R-value is for uncompressed insulation, but is also acceptable for continuous insulation



# ✓ Slab-on-Grade Floor Insulation

- Meet or exceed values in appropriate table for climate zone (includes R-value and depth or width of insulation)
- Be installed around the perimeter to the distance specified
  - Inside foundation wall – extend downward from top of slab a minimum distance specified or to the top of the footing, whichever is less
  - Outside foundation wall – extend from top of the slab or downward to at least the bottom of the slab and then horizontally to a minimum distance specified





# Opaque Doors

- Meet or exceed maximum U-factors in appropriate table for climate zone

Opaque Elements	Nonresidential		Residential		Semih heated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
<i>Roofs</i>						
Insulation Entirely above Deck	U-0.063	R-15.0 ci	U-0.048	R-20 ci	U-1.282	NR
Metal Building	U-0.065	R-19.0	U-0.055	R-13.0 + R-13.0	U-1.280	NR
Attic and Other	U-0.034	R-30.0	U-0.027	R-38.0	U-0.614	NR
<i>Walls, Above Grade</i>						
Mass	U-0.580	NR	U-0.151*	R-5.7 ci*	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-1.180	NR
Steel Framed	U-0.124	R-13.0	U-0.084	R-13.0 + R-3.8 ci	U-0.352	NR
Wood Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.292	NR
<i>Wall, Below Grade</i>						
Below Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
<i>Floors</i>						
Mass	U-0.322	NR	U-0.322			
Steel Joist	U-0.350	NR	U-0.350			
Wood Framed and Other	U-0.282	NR	U-0.282			
<i>Slab-On-Grade Floors</i>						
Unheated	F-0.730	NR				
Heated	F-1.020	R-7.5 for				
<i>Opaque Doors</i>						
Swinging	U-0.700					
Non-Swinging	U-1.450		U-1.450		U-1.450	

Opaque Doors  
Swinging  
Non-Swinging

U-0.700  
U-1.450

U-0.700  
U-1.450

U-0.700  
U-1.450

# ✓ Fenestration

- Criteria apply to fenestration, including windows, glass doors, glass block, plastic panels, and skylights
- Compliance
  - Meet or exceed maximum U-factors in table
  - Meet or exceed minimum SHGC in table
  - Use NFRC ratings or default values in Appendix A



# ✓ Fenestration Area

- Total vertical fenestration area to be  $< 40\%$  of gross wall area
  - Including both fixed and operable vertical fenestration
- Total skylight area to be  $< 5\%$  of gross roof area
  - Including glass skylights, plastic skylights with a curb, and all skylights without a curb



# Fenestration U-Factor

- U-factor not greater than specified in Tables 5.5-1 through 5.5-8





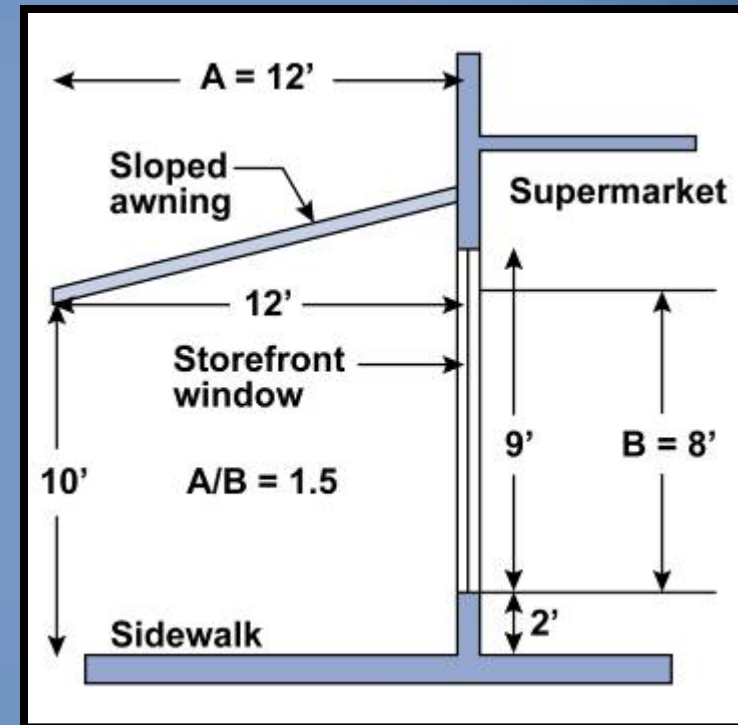
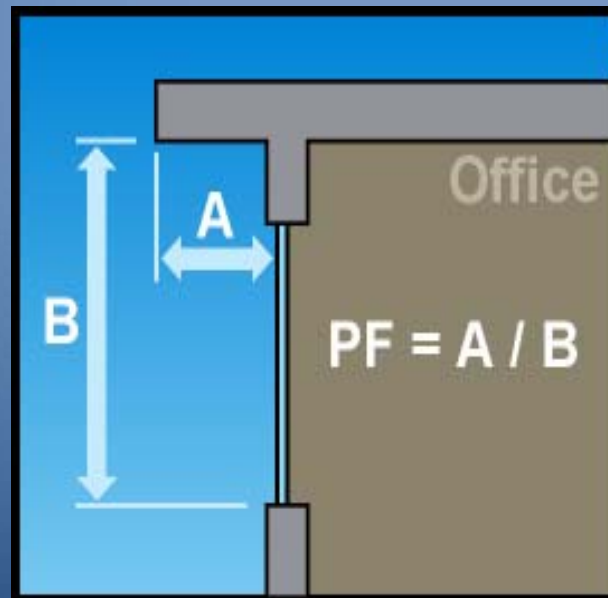
# ✓ Fenestration SHGC

- Vertical fenestration
  - SHGC values < Table value for appropriate total vertical fenestration area
- Skylights
  - SHGC values < Table value for appropriate total skylight area
- No SHGC requirements for semiheated spaces
- No criteria for Visible Light Transmittance in Prescriptive Building Envelope Option, but there are minimum criteria in the Trade-Off Option (Details in Appendix C)
- Exceptions



# ✓ Overhangs

- Standard credits permanent overhangs by adjustment to SHGC
- Size of overhang is determined by projection factor



# ✓ Building Envelope Trade-Off Option

- Building complies if
  - It satisfies the provisions of 5.1, 5.4, 5.7, and 5.8
  - Envelope performance factor (EPF) of proposed building is  $\leq$  EPF of budget building
    - EPF considers only the building envelope components and is calculated using procedures in Normative Appendix C
    - Schedules of operation, lighting power, equipment power, occupant density, and mechanical systems to be the same for both the proposed building and the budget building



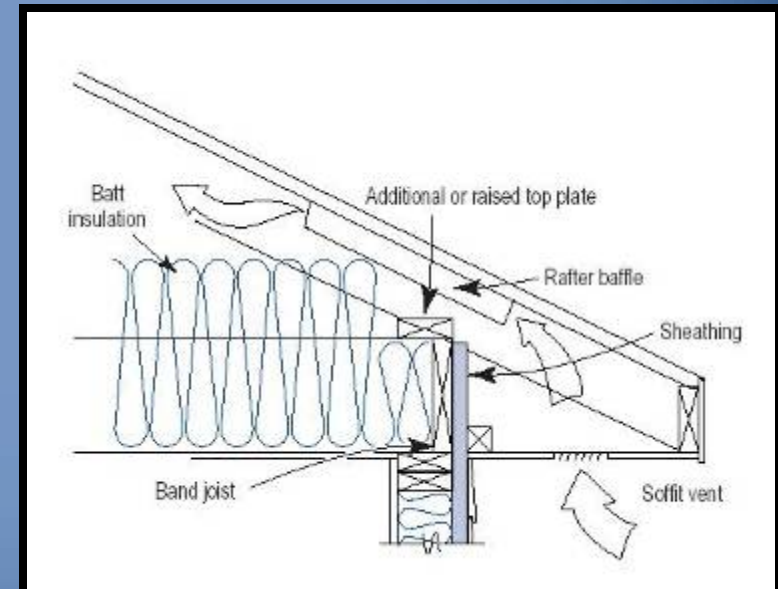
# ✓ Product Information and Installation Requirements

- Labeling of Building Envelope Insulation (*Section 5.8.1.1*)
- Compliance with Manufacturers' Requirements (*Section 5.8.1.2*)
- Loose-Fill Insulation Limitation (*Section 5.8.1.3*)
- Baffles (*Section 5.8.1.4*)
- Substantial Contact (*Section 5.8.1.5*)
- Recessed Equipment (*Section 5.8.1.6*)
- Insulation Protection (*Section 5.8.1.7*)
- Location of Roof Insulation (*Section 5.8.1.8*)
- Extent of Insulation (*Section 5.8.1.9*)



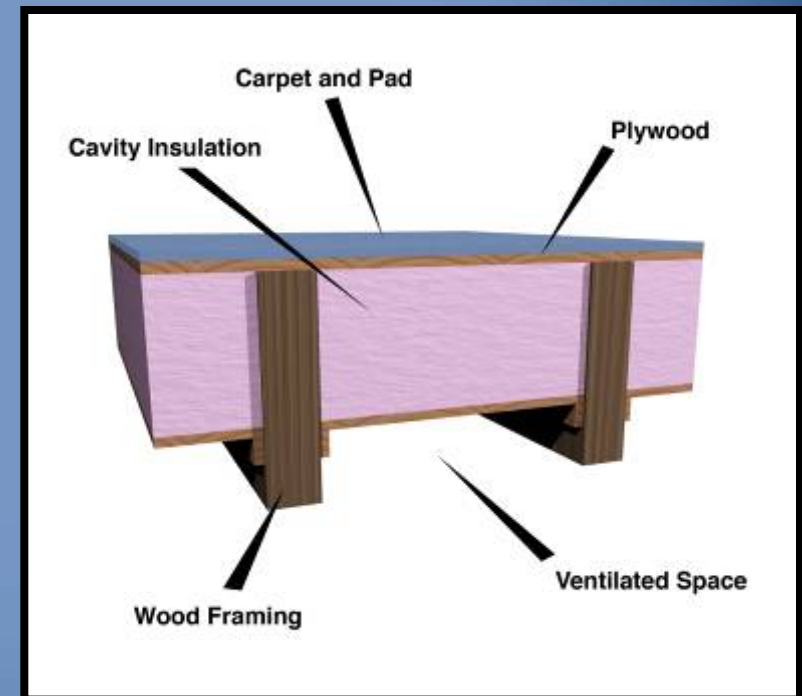
# ✓ Insulation Installation

- Per manufacturer's instructions
- Achieve rated R-value
- No open-blown or poured loose-fill insulation when ceiling slope is  $> 3/12$
- If eave vents installed
  - Provide baffling of air vents to deflect incoming air above the surface of the insulation
- Exception
  - Metal buildings – if roof and wall insulation is compressed between roof or wall skin and the structure



# ✓ Insulation - Substantial Contact

- Install insulation in a permanent manner in substantial contact with inside surface
- Flexible batt insulation in floor cavities
  - Supported in a permanent manner by supports no more than 24 in. on center (o.c.)



# ✓ Recessed Equipment

- Do not recess equipment to affect insulation thickness
  - Lighting fixtures
  - HVAC equipment (includes wall heaters, ducts, and plenums)
  - Other
- Except when
  - Total combined area affected (include necessary clearances) is < 1% of opaque area of the assembly, OR
  - Entire roof, wall, or floor is covered with insulation to the full depth required, OR
  - Effects of reduced insulation are included in area-weighted calculations

# ✓ Insulation Protection

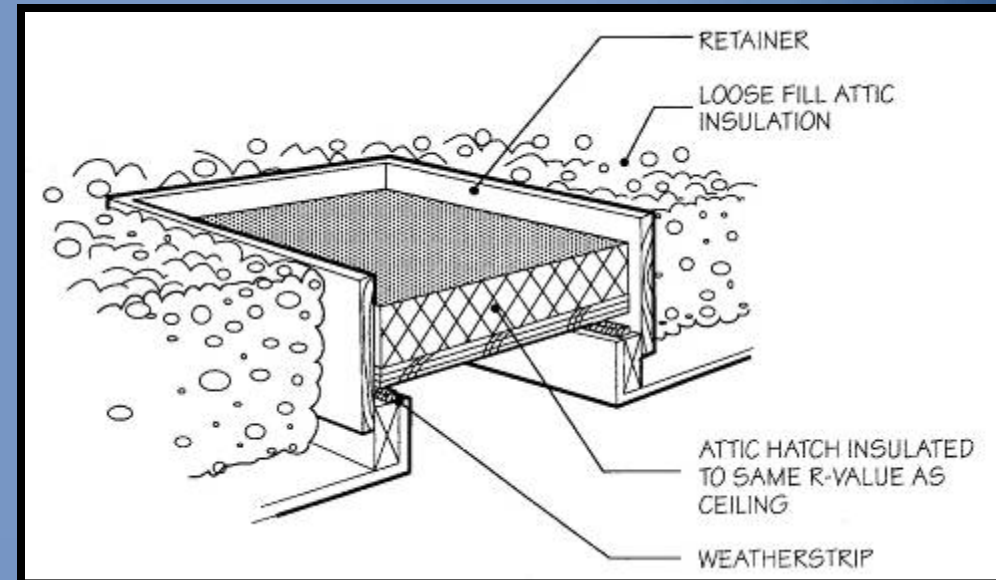
- Insulation Protection

- Cover exterior insulation with protective material

- Sunlight
- Moisture
- Landscaping operations
- Equipment maintenance
- Wind

- Access to attics and mechanical rooms without damaging or compressing insulation

- Insulation materials in ground contact to have a water absorption rate  $\leq 0.3\%$  (ASTM C272)





# ✓ Suspended Ceilings

- Roof Insulation
  - Not installed on a suspended ceiling with removable ceiling panels





# Fenestration and Doors

- U-factors
  - NFRC 100 or
  - Assemblies listed in Appendix A
- SHGC
  - NFRC 200 or
  - Assemblies listed in Appendix A
- Visible Light Transmittance
  - NFRC 200 when building envelope trade-off option is used



# ✓ U-Factor

- Skylights – determine for a slope of  $20^\circ$  above the horizontal
- Labeled and certified by manufacturer
- Exceptions
  - Glazed wall systems in vertical fenestration and skylights – may use U-factors in A.8.1
  - A8.2 acceptable for other vertical fenestration
  - A7 acceptable for opaque doors
  - ANSI/DASMA 105 acceptable for garage doors



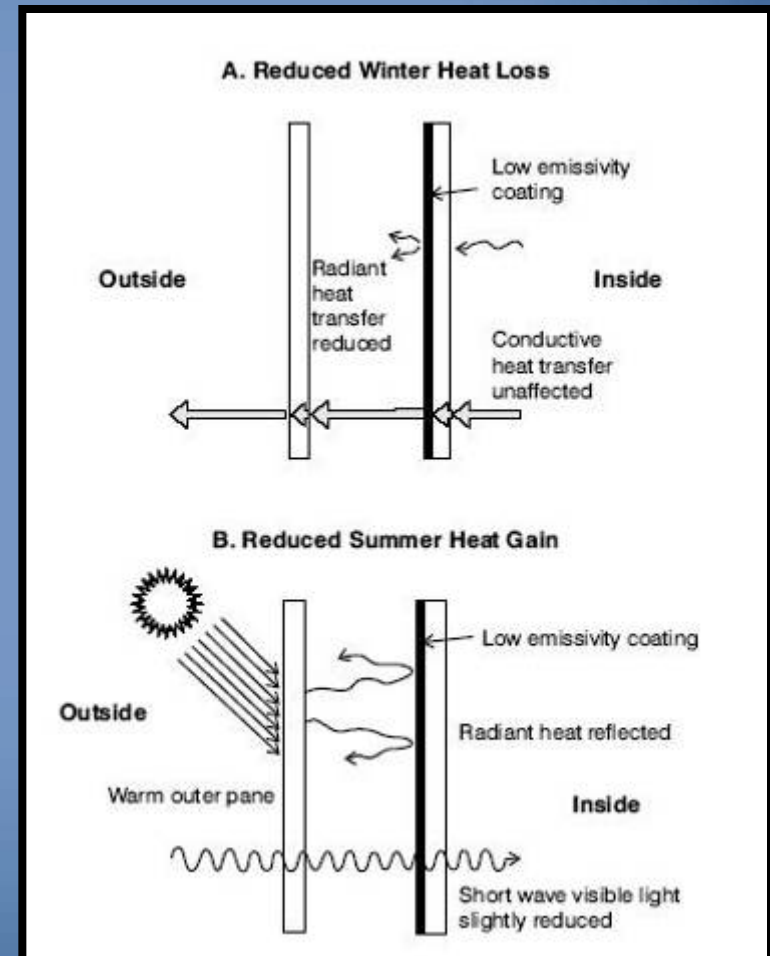


# Solar Heat Gain Coefficient (SHGC)

- The glazing's effectiveness in rejecting solar heat gain
- NFRC 200
- Exceptions
  - $SC \times 0.86$  is acceptable for overall fenestration area (NFRC 300)
  - SHGC of center-of-glass is acceptable (NFRC 300) for overall fenestration area
  - SHGC from A8.1 for glazed wall systems in vertical fenestration and skylights
  - SHGC from A8.2 for other vertical fenestration



- Part of a system for rating window performance
  - used by the National Fenestration Rating Council (NFRC)
- Gradually replacing shading coefficient (SC) in product literature and design standards
  - convert SC to SHGC by multiplying the SC value by 0.86



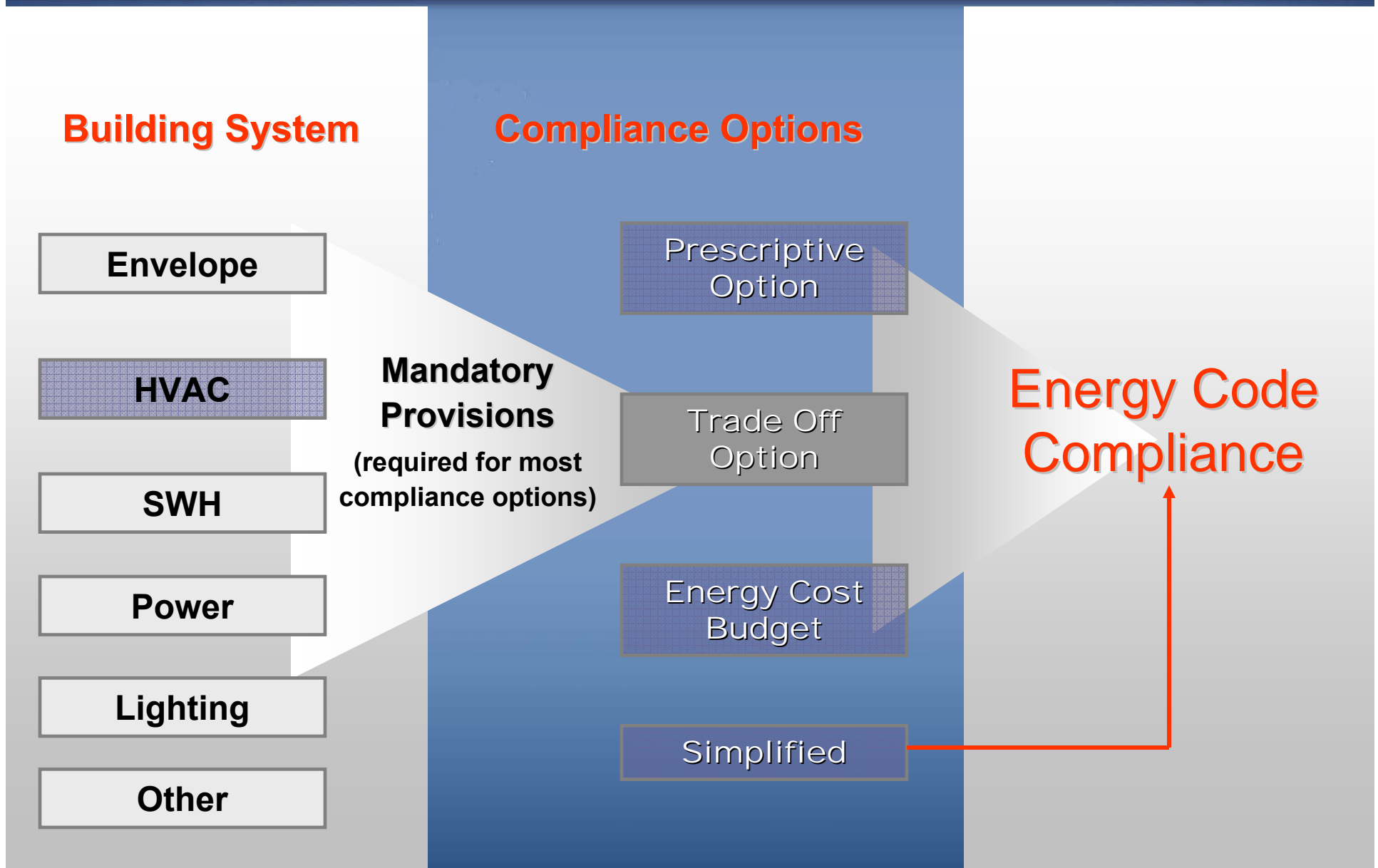


# Visible Light Transmittance

- A measure of the amount of visible light that passes through fenestration
- Affected by:
  - composition of the glass
  - coatings
  - internal shading devices
- Relationship between VLT and SHGC
  - Daylighting without excessive solar gain– VLT at least 1.2 x SHGC



# HVAC Compliance



# ✓ HVAC Alterations

- **Equipment** - New equipment shall meet the minimum efficiency requirements
- **Cooling systems**
  - New cooling systems installed to serve previously uncooled spaces shall comply with this section
  - Alterations to existing cooling systems shall not decrease economizer capacity (unless economizer tradeoff is used)
- **Ductwork** - New and replacement ductwork shall comply with applicable requirements
- **Piping** - New and replacement piping shall comply with applicable requirements





# ✓ HVAC Alterations

- Alterations to the building HVAC system shall comply with the requirements of Section 6
  - Exceptions that are allowed:
    - Equipment being **modified or repaired** (not replaced)
      - provided such modifications will not result in an increase in the annual energy consumption
    - Equipment being **replaced or altered** which requires extensive revisions to other systems and such replaced or altered equipment is a like-for-like replacement
    - **Refrigerant change** of existing equipment
    - **Relocation** of existing equipment
    - **Ducts and pipes** where there is insufficient space or access to meet these requirements



# HVAC Compliance Paths

- Section 6.2
- You have to follow Sections
  - 6.1 **General**,
  - 6.7 **Submittals**, and
  - 6.8 **Minimum Equipment Efficiency**,
- And then you can follow either
  - Section 6.3 **Simplified Approach** OR
  - Sections 6.4 **Mandatory Provisions** and 6.5 **Prescriptive Path**

Alternatively, you can follow Section 11 (ECB), in which case Section 6.4 is mandatory



# Simplified Approach Option

- Limited to...
  - Buildings with 1 or 2 stories
  - Buildings < 25,000 ft<sup>2</sup>
  - Single-zone systems (unitary or split)
  - Air-cooled or evaporatively cooled



# ✓ Simplified Approach Option *(cont'd)*

- The system shall have an economizer, unless the economizer Trade-off Option is used
  - Limited to unitary systems
  - Requires higher minimum cooling efficiency (EER)
  - Trade-off EER by
    - System size
    - Climate zone



**Table 6.3.2**

# ✓ Simplified Approach Option *(cont'd)*

- Manual changeover or dual set-point thermostat
- Heat pump supplementary control
- No reheat or simultaneous heating and cooling for humidity control
- Time clocks (except hotel/motel guest rooms and systems requiring continuous operation)
- Piping and ductwork insulated

# ✓ Simplified Approach Option *(cont'd)*

- Balancing of ducted systems
- Interlocked thermostats for separate heating and cooling
- Exhaust > 300 cfm: gravity or motorized dampers unless operated continuously
- System > 10,000 cfm: optimum start controls



# HVAC Mandatory Provisions

- Minimum Equipment Efficiency (*Section 6.4.1*)
- Load Calculations (*Section 6.4.2*)
- Controls (*Section 6.4.3*)
- HVAC System Construction and Insulation (*Section 6.4.4*)
- Completion Requirements (*Section 6.4.5*)



# ✓ Equipment Covered

- Package air conditioners and condensing units
- Heat pumps (air, water, and ground source)
- Packaged terminal and room air conditioners
- Chillers including absorption chillers
- Furnaces and unit heaters
- Boilers
- Heat rejection equipment





# Mechanical Equipment Efficiency

- Tables 6.8.1A – 6.8.1G
- Tables 6.8.1H-6.8.1J used for water cooled centrifugal chillers that operate at non-standard rating conditions
- Combination HVAC and water heating systems to meet all requirements for appropriate space heating or cooling category
- Gas-fired and oil-fired forced air furnaces with input ratings  $\geq 225,000$  Btu/h to have intermittent or interrupted ignition device and have either power venting or a flue damper
- All furnaces with input ratings  $\geq 225,000$  Btu/h, including electric furnaces, not located in conditioned space, to have jacket losses  $\leq 0.75\%$  of the input rating

# ✓ Verification of Equipment Efficiencies

Equipment efficiency information from manufacturers verified as follows:

- EPACK equipment – to comply with DOE certification requirements
- If certification program exists for covered product and includes provisions for verification and challenge of equipment efficiency ratings, product listed in program OR
- If product not listed in program, ratings verified by an independent laboratory test report OR
- If no certification program exists, equipment efficiency ratings supported by data furnished by manufacturer OR
- Where components from different manufacturers are used, system designer specifies components whose combined efficiency meets Section .4.1
- Products in Table 6.8.1G shall have efficiency ratings supported by data furnished by manufacturer.

# ✓ Labeling

- Mechanical equipment (6.4.1.5.1) – equipment not covered by NAECA shall carry a permanent label stating equipment complies with 90.1
- Packaged terminal air conditioners (6.4.1.5.2) – packaged terminal air conditioners and heat pumps with sleeve sizes < 16 in. high and 42 in. wide shall be factory labeled as follows:
  - *Manufactured for replacement applications only: not to be installed in new construction projects*



# ✓ Load Calculations

- Must calculate heating and cooling system design loads
- Must base calculations on generally accepted engineering standards and handbooks



# ✓ Controls – Zone Thermostatic and Dead Band

- Required for each zone
  - Perimeter can be treated differently
- Dead band controls
  - Thermostats must have at least a 5°F dead band
  - Exceptions
    - Thermostats that require manual changeover between heating and cooling modes
    - Special occupancy or applications where wide temperature ranges aren't acceptable (e.g., retirement homes) and approved by adopting authority



# ✓ Controls – Setpoint Overlap Restriction

- If limit switches, mechanical stops, or software programming for DDC systems are used
  - means will be provided to prevent the heating setpoint from exceeding the cooling setpoint minus any applicable proportional band



# ✓ Controls – Off-Hour

- Automatic shutdown
- Setback controls
- Optimum start
- Zone isolation
- Exceptions, HVAC systems
  - with heating/cooling capacity < 15,000 Btu/h
  - intended to operate continuously



# ✓ Controls - Automatic Shutdown

- Automatic 7-day/week time clock with 10-hour battery backup
  - Exception: 2-day/week thermostat for residential applications
- Each control to have
  - Occupant sensor, OR
  - Manually-operated timer with maximum two hour duration, OR
  - Security system interlock
- Exception
  - Residential occupancies allowed to operate with only 2 different time schedules/wk



# ✓ Controls - Setback

- Climate Zones 2-8
  - Lower heating setpoint to 55°F or less
- Climate Zones 1b, 2b, 3b (hot/dry)
  - Automatically restart, temporarily operate
    - Raise cooling setpoint to 90°F or higher OR
    - Prevent high space humidity levels

# ✓ Controls - Optimum Start

- Individual heating and cooling air distribution systems with
  - Total design supply air capacity  $> 10,000$  cfm
  - Served by one or more supply fans
- Control algorithm to at least be a function of
  - Difference between space temperature and occupied setpoint and amount of time prior to scheduled occupancy



# ✓ Controls - Zone Isolation

- Applies to
  - Each floor in a multistory building
  - Maximum 25,000 ft<sup>2</sup> zone on one floor
- Requirements
  - Isolation devices to shut off outdoor and exhaust airflow when > 5,000 cfm
  - Central systems shall be capable of stable operation with one isolation zone
    - Capable of separate time schedules for each isolation zone



## Controls – Ventilation System *(cont'd)*

- Stair and Shaft Vent dampers
- Gravity Hoods, Vents, and Ventilator Dampers



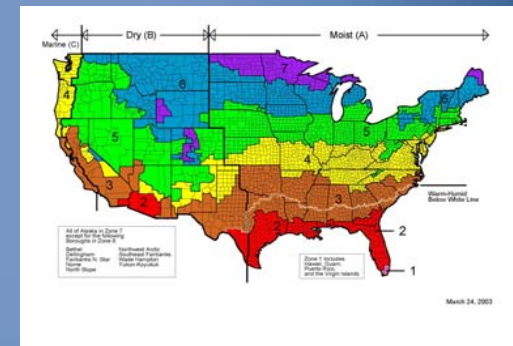
# ✓ Stair and Shaft Vents

- Motorized dampers
  - Can be automatically closed during normal building operation
  - Interlocked to open as required by fire and smoke detection systems



# ✓ Gravity Hoods, Vents, and Ventilators

- Motorized dampers to automatically shut when spaces served are not in use
- Exceptions
  - Gravity dampers okay in buildings
    - < 3 stories in height **above grade**
    - Of any height in climate zones 1 - 3
  - Ventilation systems serving unconditioned spaces



# ✓ Controls - Shutoff Damper

- Motorized dampers for outdoor air supply and exhaust systems
- Ventilation outside air dampers to be capable of automatically shutting off during
  - Preoccupancy building warm up, cool down, and setback  
(Except when ventilation reduces energy costs or when ventilation must be supplied to meet code requirements)

# ✓ Controls - Shutoff Damper

- Exceptions:
  - Gravity dampers okay in buildings
    - < 3 stories in height
    - Of any height in climate zones 1-3
  - Outdoor-air intake or exhaust < 300 cfm
- Table 6.4.3.3.4 provides maximum leakage rates for outdoor air supply and exhaust dampers





# Dampers

- Where OA supply and exhaust air dampers are required by Section 6.4.3.4
  - They shall have a maximum leakage rate when tested in accordance with AMCA Standard 500 as indicated in Table 6.4.3.4.4





# Ventilation Fan Controls

- Fans with motors  $> 0.75$  hp shall have automatic controls complying with Section 6.4.3.3.1 that are capable of shutting off fans when not required
- Exception
  - HVAC systems intended to operate continuously



# ✓ Heat Pump Auxiliary Heat Control

- Controls to prevent supplementary heat when heat pump can handle the load
- Exception
  - Heat pumps
    - With minimum efficiency regulated by NAECA
    - With HSPF rating meeting Table 6.8.1B  
(Includes all usage of internal electric resistance heating)





## Controls - Humidifier Preheat

- Automatic valve to shut off preheat when humidification isn't required





# Controls - Humidification and Dehumidification

- Provide means to prevent simultaneous operation of humidification and dehumidification equipment
  - Limit switches, mechanical stops, or software programming (DDC systems)
- Exceptions
  - Zones served by desiccant systems, used with direct evaporative cooling in series
  - Systems serving zones where specific humidity levels are required and approved by jurisdiction
    - Museums and hospitals



# ✓ Controls - Freeze Protection and Snow/Ice

- Automatic controls for
  - Freeze protection systems
    - outside air temperatures  $> 40^{\circ}\text{F}$  or when conditions of protected fluid will prevent freezing
  - Snow- and ice-melting systems
    - pavement temperature  $> 50^{\circ}\text{F}$  and no precipitation is falling and outdoor temperature  $> 40^{\circ}\text{F}$



# ✓ Ventilation Controls for High-Occupancy Areas

- *DCV* must be provided for each zone with a area  $> 500$  ft<sup>2</sup> and the design occupancy  $> 40$  people/1000 ft<sup>2</sup> where the HVAC system has:
  - An air-side economizer,
  - Automatic modulating control of the OSA dampers, or
  - A design outdoor airflow  $> 3,000$  cfm

*Demand control ventilation (DCV)*: a ventilation system capability that provides for the automatic reduction of outdoor air intake below design rates when the actual occupancy of spaces served by the system is less than design occupancy.



# Ventilation: High Occupancy Exceptions

- Exceptions:
  - Systems with exhaust-air energy recovery complying with Section 6.5.6.1
  - Multiple zone systems without DDC to the zone level
  - Systems with a design OA airflow  $<1,200$  cfm
  - Spaces where supply-exhaust  $<1,200$  cfm





# ✓ HVAC System Construction and Insulation

- Insulation installed in accordance with industry-accepted standards
- Insulation protection
- Duct and plenum insulation
- Piping insulation
- Duct sealing
- Duct leakage tests



- Insulation installed in accordance with industry-accepted standards
- Insulation
  - Protected from damage due to sunlight, moisture, equipment maintenance, and wind
  - Exposed to weather to be suitable for outdoor service
  - Covering chilled water piping, refrigerant suction piping, or cooling ducts located outside the conditioned space to include a vapor retardant located outside the insulation, all penetrations and joints of which to be sealed



# Duct and Plenum Insulation

- All supply and return ducts and plenums to be insulated per Tables 6.8.2A and 6.8.2B
- Exceptions
  - Factory-installed plenums, casings, or ductwork furnished as part of HVAC equipment
  - Ducts located in heated, semi-heated, or cooled spaces
  - For runouts  $< 10$  ft in length to air terminals or air outlets, the R-value need not exceed R-3.5
  - Backs of air outlets and outlet plenums exposed to unconditioned or indirectly conditioned spaces with face areas  $> 5$  ft<sup>2</sup> need not exceed R-2; those  $\leq 5$  ft<sup>2</sup> need not be insulated



# Piping Insulation

- Table 6.8.3
- Exceptions
  - Factory-installed
  - Piping conveying fluids
    - design operating temperature range between 60°F-105°F, inclusive
    - that haven't been heated or cooled through the use of nonrenewable energy or where heat gain or heat loss will not increase energy usage
  - Hot water piping between shut off valve and coil, not > 4 ft in length, when located in conditioned spaces
  - Pipe unions in heating systems (steam, steam condensate, and hot water)





# Duct Sealing

- Table 6.4.4.2A
- Requirements of 6.4.4.2
- Based on standard industry practice and definitions

**Table 6.4.4.2A**  
**Minimum Duct Seal Level**

Duct Location	Duct Type			
	Supply		Exhaust	Return
	≤2 in. w.c. <sup>†</sup>	>2 in. w.c. <sup>†</sup>		
Outdoors	A	A	C	A
Unconditioned Spaces	B	A	C	B
Conditioned Spaces <sup>**</sup>	C	B	B	C

\* See Table 6.4.4.2B definition of Seal Level.

† Duct design static pressure classification.

\*\* Includes indirectly conditioned spaces such as return air plenums.



# Duct Leakage Tests

- Designed > 3 in. w.c.
  - Leak tested
  - Representative sections  $\geq 25\%$  of the total installed duct area shall be tested
  - Ratings > 3 in. w.c. to be identified on drawings
  - Maximum permitted duct leakage

- $L_{\max} = C_L P^{0.65}$

Where  $L_{\max}$  = maximum permitted leakage in cfm/100 ft<sup>2</sup> duct surface area





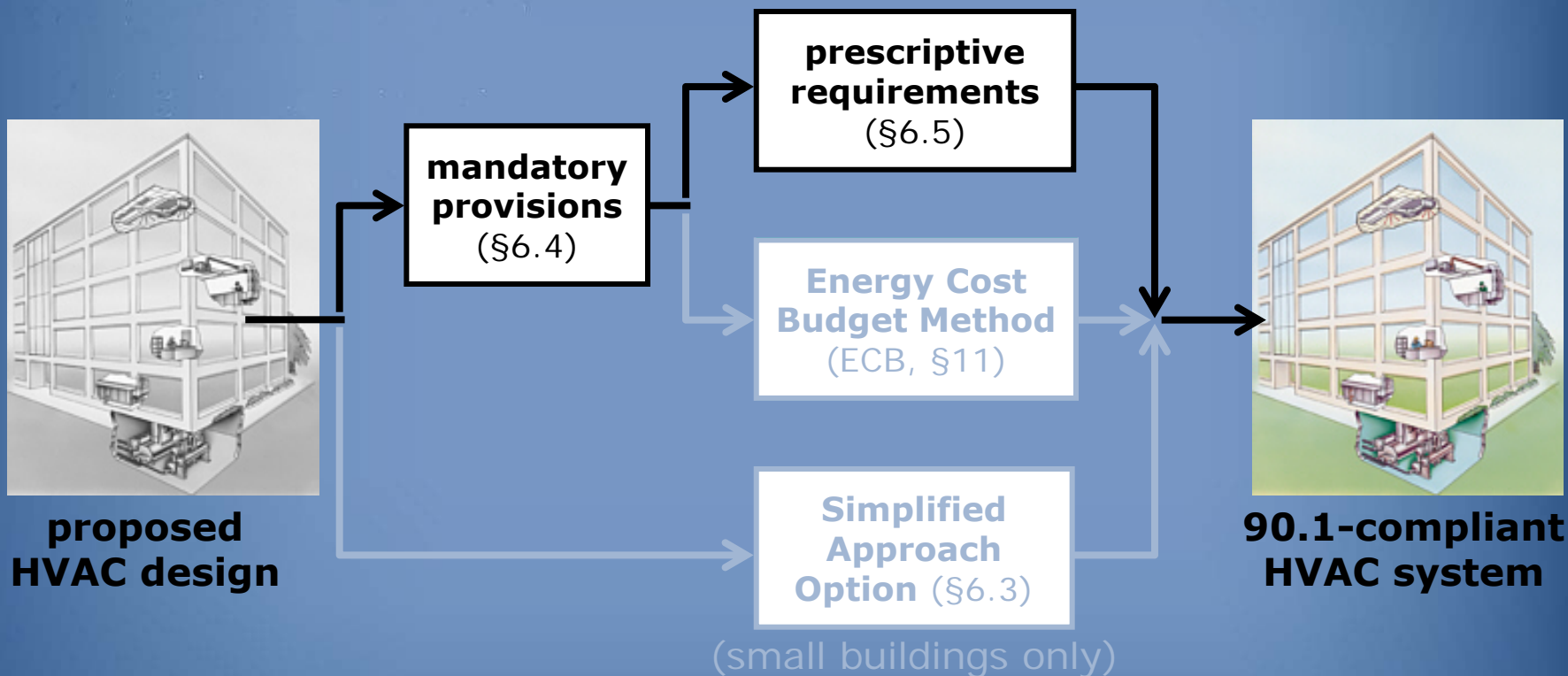
# Completion Requirements

- Refers to Section 6.7 for Submittal and Completion Requirements including
  - Record drawings
  - Operating and maintenance manuals
  - System balancing
  - System commissioning





# Prescriptive Requirements





# ✓ HVAC Prescriptive Path

- Economizers (*Section 6.5.1*)
- Simultaneous Heating and Cooling Limitation (*Section 6.5.2*)
- Air System Design and Control (*Section 6.5.3*)
- Hydronic System Design and Control (*Section 6.5.4*)
- Heat Rejection Equipment (*Section 6.5.5*)
- Energy Recovery (*Section 6.5.6*)
- Exhaust Hoods (*Section 6.5.7*)
- Radiant Heating Systems (*Section 6.5.8*)
- Hot Gas Bypass Limitation (*Section 6.5.9*)





# Economizers

- Climate and size dependent (Table 6.5.1)
- There are LOTS of exceptions
- Can use air economizers
  - 100% of design supply air
  - Sequenced with mechanical cooling equipment
  - High limit shutoff
  - Dampers
- Can use water economizers
  - 100% of expected system cooling load at 50°F DB, 45°F WB
  - Maximum pressure drop limitation





# Economizer Exceptions

- Exceptions:
  - Cooling capacity - Table 6.5.1
  - Systems with gas phase air cleaning per Standard 62
  - Where >25% of the air must be humidified >35°Fdp
  - Systems with condenser heat recovery per 6.5.6.2
  - Residential systems <5X limits in Table 6.5.1
  - Systems with a balance point  $\leq 60^{\circ}\text{F}$
  - Systems expected to operate < 20hrs/wk
  - Systems serving zones with refrigerated casework
  - Where cooling efficiency exceeds Table 6.3.2





# Economizers (Table 6.5.1)

Climate zone

Cooling capacity for which an economizer is required

**1a, 1b, 2a, 3a, 4a**  
(Miami, St. Louis, Charlotte)

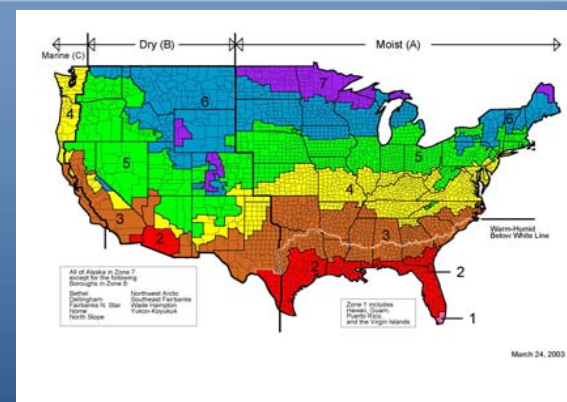
**Economizer unnecessary**

**2b, 5a, 6a, 7, 8**  
(Yuma, Chicago, Edmonton)

**≥ 135,000 Btu/h**

**3b, 3c, 4b, 4c, 5b, 5c, 6b**  
(Denver, Lubbock, Vancouver)

**≥ 65,000 Btu/h**



# ✓ Design Capacity – Air Economizers

- System capable of modulating outside air and return air dampers to provide up to 100% of the design supply air quantity as outside air for cooling



# ✓ Control Signal

- Dampers capable of being sequenced with the mechanical cooling equipment and shall not be controlled by only mixed air temperature
- Exception
  - Systems controlled from space temperature (such as single-zone systems)



# ✓ High Limit Shutoff

- Automatically reduce outdoor air intake to minimum outdoor air quantity when outdoor air intake will no longer reduce cooling energy usage
- Control types for specific climates from Table 6.5.1.1.3A
- Settings from Table 6.5.1.1.3B



# Dampers

- Return air and outdoor air dampers to meet the damper leakage specified in 6.4.3.4.4





# ✓ Relief of Excess Outside Air

- Means to relieve excess outdoor air during economizer operation to prevent overpressurizing the building
- Outlet located to avoid recirculation into the building



# ✓ Design Capacity – Water Economizers

- System capable of cooling supply air by indirect evaporation and providing up to 100% of expected system cooling load at outside air temperatures of 50°F dry bulb/45°F wet bulb and below
- Exception
  - You can also meet this requirement if your design can meet 100% of expected cooling load at 45°F dry bulb/40°F wet bulb



# ✓ Maximum Pressure Drop

- Precooling coils and water-to-water heat exchangers to have either
  - Water-side pressure drop of  $< 15$  ft of water
  - OR
  - Bypassed when not in use

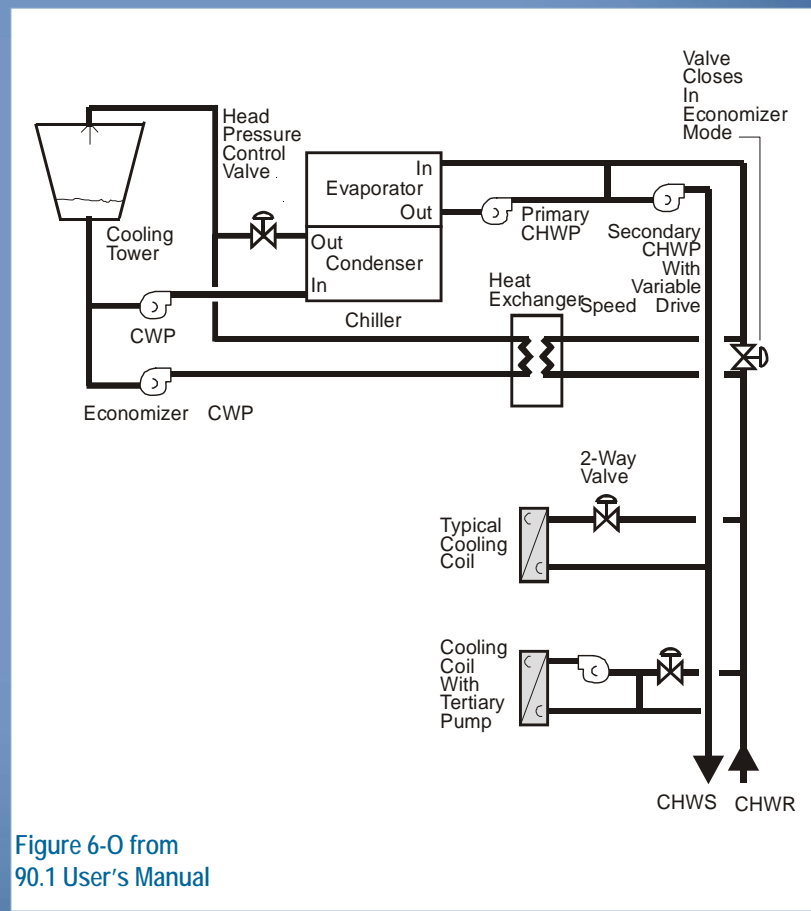


Figure 6-0 from  
90.1 User's Manual



# Integrated Economizer Control

- Economizers must be integrated with mechanical cooling systems and be capable of providing partial cooling even when additional mechanical cooling is required
- Some exceptions to this



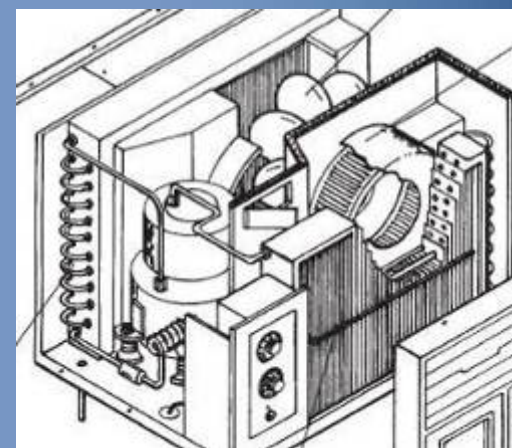
# ✓ Economizer Heating System Impact

- Designed so economizer operation doesn't increase the building heating energy use during normal operation
- Exception
  - Economizers on VAV systems that cause zone level heating to increase due to a reduction in supply air temperature



# ✓ Zone Controls

- Capable of operating in sequence the supply of heating and cooling energy to the zone
- Controls prevent
  - Reheating
  - Recooling
  - Mixing or simultaneously supplying air previously heated or cooled
  - Other simultaneous operation of heating and cooling systems to the same zone





# Zone Controls - Exceptions

- Zones for which volume of air that is reheated, recooled, or mixed is no greater than the larger of the following
  - Volume of outside air to meet 6.2 of ASHRAE 62 for the zone
  - 0.4 cfm/ft<sup>2</sup> of zone conditioned floor area
  - 30% of zone design peak supply
  - 300 cfm for zones whose peak flow rate totals no more than 10% of the total fan system flow rate
  - Any higher rate that can be demonstrated to jurisdiction to reduce overall system annual energy usage
- Zones where special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates are such that the variable air volume systems are impractical



# ✓ Hydronic System Controls

- Limit heating and cooling of fluids previously heated or cooled mechanically per 6.5.2.2.1 through 6.5.2.2.3





# ✓ Three-Pipe System

- No common return system for both hot and chilled water



# ✓ Two-Pipe Changeover System

- Common distribution system acceptable if
  - Deadband from one mode to another is  $\geq 15^{\circ}\text{F}$  outside air temperature
  - Controls to allow operation of  $\geq 4$  hours before changing over
  - Reset controls so heating and cooling supply temperatures at changeover point no more than  $30^{\circ}\text{F}$  apart





# Hydronic (Water Loop) Heat Pump Systems

- Controls to provide heat pump water supply temperature deadband of at least 20°F between initiation of heat rejection and heat addition by central devices
- Cooling tower bypass or cooling tower isolation dampers
- A two-position valve at each hydronic heat pump for hydronic systems having a total pump system power > 10 hp
- Exception
  - If system loop temperature optimization controller is used, deadband < 20°F is allowed



# ✓ Dehumidification

- Humidistatic controls to prevent
  - Reheating
  - Mixing of hot and cold air streams
  - Heating and cooling of same air stream



# ✓ Dehumidification Exceptions

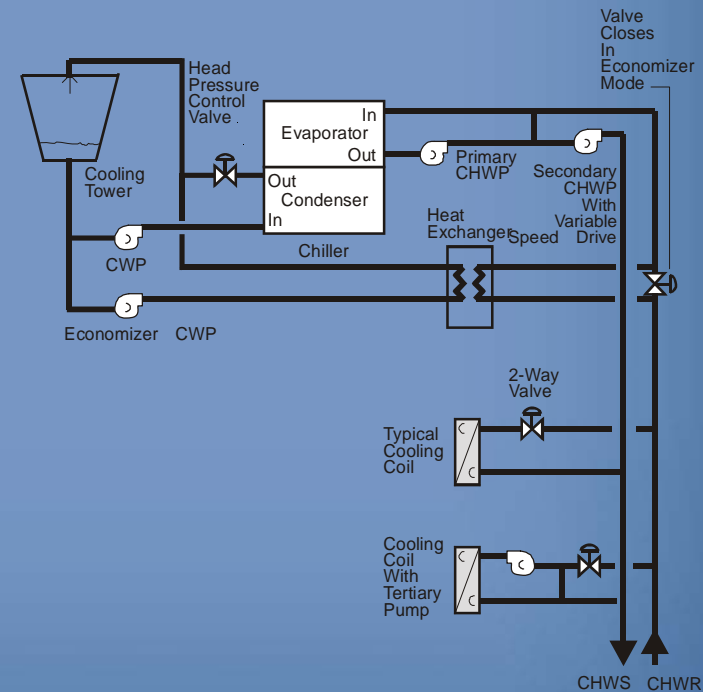
- Systems capable of reducing supply air flow to 50%, or to minimum ventilation
- Systems under 6.67 tons that can unload at least 50%
- Systems smaller than 3.3 tons
- Process applications
- 75% of reheat or recool energy is recovered or solar





# Humidification

- Systems with hydronic cooling and humidification systems designed to maintain inside humidity at  $> 35^{\circ}\text{F}$  dewpoint temperature shall use a water economizer if required by 6.5.1



# ✓ Air System Design and Control

- HVAC systems with total fan system power > 5 hp to meet 6.5.3.1 through 6.5.3.2
  - Fan Power Limitation
  - VAV Fan Control
    - Part Load Fan Power Limitation
    - Static Pressure Sensor location
    - Set Point Reset



# ✓ Fan Power Limitation

- Table 6.5.3.1
- Allowable fan system power may be adjusted if
  - Air systems require air treatment or filtering systems with pressure drops  $> 1$  in. w.c. when filters are clean, or heat recovery coils or devices, or direct evaporative humidifiers/coolers, or other devices to serve process loads in the airstream
  - design room temperature – supply air temp at cooling design condition =  $> 20^{\circ}\text{F}$ , allowable fan system power may be adjusted
- Exceptions





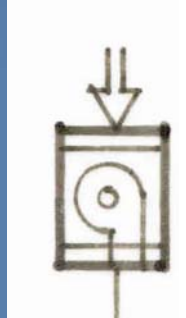
# Motor Nameplate Horsepower

- Selected fan motor to be no larger than first available motor size greater than bhp
- Fan bhp on design documents
- Exceptions
  - Fans  $< 6$  bhp, where first available motor larger than bhp has nameplate rating within 50% of bhp, next larger nameplate motor size may be selected
  - Fans  $\geq 6$  bhp, where first available motor larger than bhp has nameplate rating within 30% of bhp, next larger nameplate motor size may be selected



# ✓ Part-Load Fan Power Limitation

- Individual VAV fans with motors  $\geq 10$  hp
  - Must have either:
    - Variable Speed Drive
    - Vane axial fan with variable-pitch fan blades
    - Other controls and devices to result in fan motor demand  $\leq 30\%$  of design wattage at 50% of design air volume when static pressure set point =  $1/3$  of total design static pressure, based on manufacturer's certified fan data



# ✓ Static Pressure Sensor Location

- Placed so controller set point is  $\leq 1/3$  the total design fan static pressure
  - Except for digital control systems with zone reset capabilities where it may be at the fan discharge
- Install multiple sensors in each major branch if sensor would be located downstream of a major duct split



# ✓ Set Point Reset

- For systems with direct digital control of individual zone boxes reporting to the central control panel
  - Static pressure set point reset based on zone requiring the most pressure



# ✓ Hydronic System Design and Control

- HVAC hydronic systems with total pump system power > 10 hp shall meet 6.5.4.1 – 6.5.4.4
  - Hydronic Variable Flow Systems
  - Pump Isolation
  - Chilled and Hot Water Temperature Reset
  - Hydronic (water-loop) Heat Pump Systems



# ✓ Hydronic Variable Flow

- HVAC pumping systems to include control valves
  - Designed to modulate or step open and close as a function of load
  - Designed for variable fluid flow
  - Capable of reducing flow rates to  $\leq 50\%$  of design flow rate
- Individual pumps serving variable flow systems with a pump head  $> 100$  ft and motor  $> 50$  hp
  - Have controls and/or devices resulting in pump motor demand  $\leq 30\%$  of design wattage at 50% of design water flow



# ✓ Hydronic Variable Flow - Exceptions

- Systems where
  - Minimum flow is  $<$  minimum flow required by equipment manufacturer for proper operation of equipment served by the system
  - Total pump system power  $\leq$  75 hp
- Systems that include  $\leq$  3 control valves



# ✓ Pump Isolation

- If chilled water plant has more than one chiller or boiler  
plant has more than one boiler
  - Provide for flow reduction when chiller or boiler is shut down





# ✓ Chilled and Hot Water Temperature Reset Controls

- Affects systems with design capacity  $> 300,000$  Btu/h
  - To include controls to automatically reset supply water temperatures by representative building loads (including return water temperature) or by outside air temperature
- Exceptions
  - If controls would result in improper operation
  - Hydronic systems with variable flow



# ✓ Hydronic Heat Pump

- For heat pump loops with total pump system power  $> 10$  hp
  - Two-position valves at each hydronic heat pump must be provided and interlocked to shut off water flow to the heat pump when the compressor is off
    - This basically converts the system into a variable flow system. As such, these systems must also comply with 6.3.4.1



# ✓ Heat Rejection Equipment

- Applies to heat rejection equipment used in comfort cooling systems such as
  - Air-cooled condensers
  - Open cooling towers
  - Closed-circuit cooling towers
  - Evaporative condensers
- Exceptions
  - Heat rejection devices included as an integral part of equipment listed devices whose energy usage is included in Tables 6.8.1A-6.8.1D

# ✓ Fan Speed Control

- Each fan powered by a motor  $\geq 7.5$  hp
  - Have capability to operate fan at  $\leq 2/3$  full speed
  - Have controls to automatically change the fan speed to control the leaving fluid temperature or condensing temperature/pressure of the heat rejection device
- Exceptions
  - Condenser fans serving multiple refrigerant circuits or flooded condensers
  - Installations located in climates zones 1 and 2
  - 1/3 of the fans on a multiple fan application speed controlled

# ✓ Exhaust Air Energy Recovery

- Incorporate exhaust air energy recovery in systems with
  - $\geq 70\%$  outside air and  $\geq 5000$  cfm total
  - 50% energy recovery effectiveness



# ✓ Exhaust Air Energy Recovery Exceptions

- Lab systems meeting 6.5.7.2
- Systems serving uncooled spaces that are heated to  $< 60^{\circ}\text{F}$
- Systems exhausting toxic, flammable, paint or corrosive fumes or dust
- Commercial kitchen hoods used for collecting grease or smoke
- Where  $> 60\%$  of outdoor heating energy is provided from site-recovered or site solar energy
- Heating systems in climate zones 1 through 3
- Cooling systems in climate zones 3c, 4c, 5b, 5c, 6b, 7, and 8
- Where largest exhaust source is  $< 75\%$  of the design outdoor airflow
- Systems requiring dehumidification that employ energy recovery in series with the cooling coil



# Heat Recovery for Service Water Heating

- Condenser recovery required if
  - 24 hrs per day and
  - Heat rejection  $> 6,000,000$  Btu/h and
  - SWH load  $> 1,000,000$  Btu/h
- Exceptions

# ✓ Kitchen Hoods (Exhaust)

- Hoods > 5,000 cfm to be provided with makeup air sized for at least 50% of exhaust air volume that is a) unheated or heated to more than 60°F and b) uncooled or cooled without the use of mechanical cooling
- Exceptions
  - Where hoods are used to exhaust ventilation air that would otherwise exfiltrate or be exhausted by other fan systems
  - Certified grease extractor hoods that require a face velocity no greater than 60 fpm



# ✓ Fume Hoods

- Hood systems with a total exhaust rate  $> 15,000$  cfm to have ONE of the following features
  - Operation to  $< 50\%$  design flow OR
  - Direct make up at least  $75\%$  of exhaust rate at specified conditions OR
  - Heat recovery for make-up air



# ✓ Radiant Heating Systems

- Required for unenclosed spaces except loading docks with air curtains
- “Radiant heating systems that are used as primary or supplemental enclosed space heating must be in conformance with the governing provisions of the standard”



# ✓ Hot Gas Bypass Limitation

- Not used (including other evaporator pressure control systems) unless system is designed with multiple steps of unloading or continuous capacity modulation
- Exception
  - Unitary packaged systems with cooling capacities  $\leq 90,000$  Btu/h



# Submittals

- Record drawings
- Operating and maintenance manuals
- System balancing
- System commissioning



# ✓ Drawings

- Record drawings of actual installation to building owner within 90 days of system acceptance and include, as a minimum
  - Location and performance data on each piece of equipment
  - General configuration of duct and pipe distribution system including sizes
  - Terminal air or water design flow rates

- Operating and maintenance manuals to building owner within 90 days of system acceptance and include several items



# ✓ System Balancing

- Systems shall be balanced in accordance with accepted engineering standards
- Written report for conditioned spaces  $> 5000 \text{ ft}^2$
- Minimize throttling losses
- For fans with system power  $> 1 \text{ hp}$ 
  - Adjust fan speed to meet design flow conditions



# ✓ Hydronic System Balancing

- Proportionately balanced to minimize throttling losses
- Pump impeller trimmed or pump speed adjusted to meet design flow conditions
- Each system to have either the ability to measure differential pressure increase across the pump or have test ports at each side of the pump
- Exceptions
  - Pumps with pump motors  $\leq 10$  hp
  - When throttling results in  $< 5\%$  of the nameplate hp draw, or 3 hp, whichever is greater, above that required if the impeller was trimmed





# ✓ System Commissioning

- Control elements are calibrated, adjusted, and in proper working condition
- > 50,000 ft<sup>2</sup> conditioned area
  - Except warehouses and semiheated spaces
  - Requires commissioning instructions





# Minimum Equipment Efficiency Tables

- Equipment efficiency tables 6.8.1A to 6.8.1J
- Duct Insulation Tables 6.8.2A and 6.8.2B
- Pipe Insulation Table 6.8.3



## Building System

## Compliance Options

Envelope

HVAC

SWH

Power

Lighting

Other

**Mandatory Provisions**  
(required for most compliance options)

Prescriptive Option

Trade Off Option

Energy Cost Budget

Simplified

## Energy Code Compliance



# Section 7 - Service Water Heating

- General (*Section 7.1*)
- Compliance Path(s) (*Section 7.2*)
- Mandatory Provisions (*Section 7.4*)
  - Load calculations
  - Equipment efficiency
  - Service hot water piping insulation
  - System controls
  - Pools
  - Heat traps
- Prescriptive Path (*Section 7.5*)
  - Space heating and water heating
  - Service water heating equipment
- Submittals (*Section 7.7*)



# ✓ SWH Alterations

- SWH equipment installed as a direct replacement shall meet these requirements unless there is not sufficient space or access to meet these requirements





# SWH Compliance Paths

- Section 7.2
- You have to follow Sections
  - 7.1,
  - 7.4,
  - 7.5,
  - 7.7, and
  - 7.8
- Alternatively, you can follow Section 11 (ECB), in which case Section 7.4 is mandatory

# ✓ Load Calculations

- In accordance with manufacturer's published sizing guidelines or generally accepted engineering standards and handbooks



# ✓ Equipment Efficiency

- Section 7.4.2 refers to Table 7.8 for equipment efficiencies
- Equipment not listed in Table 7.8 has no minimum performance requirements
- Exception
  - Water heaters and hot water supply boilers > 140 gal storage capacity don't have to meet standby loss requirements when
    - Tank surface is thermally insulated to R-12.5, and
    - A standing pilot light isn't installed, and
    - Gas- or oil-fired water heaters have a flue damper or fan-assisted combustion





# ✓ Service Hot Water Piping Insulation

- Table 6.8.3, Section 6
- Circulating water heater
  - Recirculating system piping, including supply and return piping
- Nonrecirculating storage system
  - First 8 ft of outlet piping
  - Inlet pipe between storage tank and heat trap
- Externally-heated pipes (heat trace or impedance heating)



# ✓ Service Water Heating System Controls

- Temperature Controls
- Temperature Maintenance Controls
- Outlet Temperature Controls
- Circulating Pump Controls



# ✓ Temperature Controls

- To allow for storage temperature adjustment from 120°F or lower to a maximum temperature compatible with the intended use
- Exception
  - If manufacturer's installation instructions specify a higher minimum thermostat setting to minimize condensation and resulting corrosion



# ✓ Temperature Maintenance Controls

- Automatic time switches or other controls
  - Set to switch off usage temperature maintenance system during extended periods when hot water is not required



# ✓ Outlet Temperature Controls

- Controls provided
  - To limit maximum temperature of water delivered from lavatory faucets in public facility restrooms to 110°F



# ✓ Circulating Pump Controls

- To limit operation to a period from the start of the heating cycle to a maximum of five minutes after the end of the heating cycle



# ✓ Pools

- Pool heaters to have readily accessible on-off switch
- Pool heaters fired by natural gas can NOT have continuously burning pilot lights
- Vapor retardant pool covers required (unless recovered or solar heat)
- Time switches required



# ✓ Heat Traps

- Noncirculating systems to have heat traps on both the inlet and outlet piping as close as practical to storage tank (if no integral heat traps)
  - Either a device specifically designed for this purpose or
  - Arrangement of tubing that forms a loop of 360° or piping that from the point of connection to the water heater includes a length of piping directed downward before connection to the vertical piping of the supply water or hot water distribution system, as applicable





# ✓ Space Heating and Water Heating

- Gas- or oil-fired space heating boiler system (complying with Section 6) is allowed to provide total space heating and water heating when ONE of the following conditions is met
  - Single boiler or component that is heating the service water has a standby loss in Btu/h not exceeding
    - $(13.3 \times pmd + 400) / n$ ; where  $pmd$  is probable maximum demand in gal/h and  $n$  is the fraction of the year when outdoor daily mean temperature is  $> 64.9^{\circ}\text{F}$
  - Jurisdiction agrees use of a single heat source will consume less energy than separate units
  - Energy input of the combined boiler and water heater system is  $< 150,000$  Btu/h
- Instructions for determining standby loss are included in this Section

# ✓ Service Water Heating Equipment

- Equipment used to provide the additional function of space heating as part of a combination (integrated) system shall satisfy all requirements for service water heating equipment



# ✓ Service Water Heating Submittals

- Authority having jurisdiction may require submittal of compliance documentation and supplemental information in accord with Section 4.2.2 of this standard



# ✓ Power Compliance

## Building System

## Compliance Options

Envelope

HVAC

SWH

Power

Lighting

Other

**Mandatory Provisions**  
(required for most compliance options)

Prescriptive Option

Trade Off Option

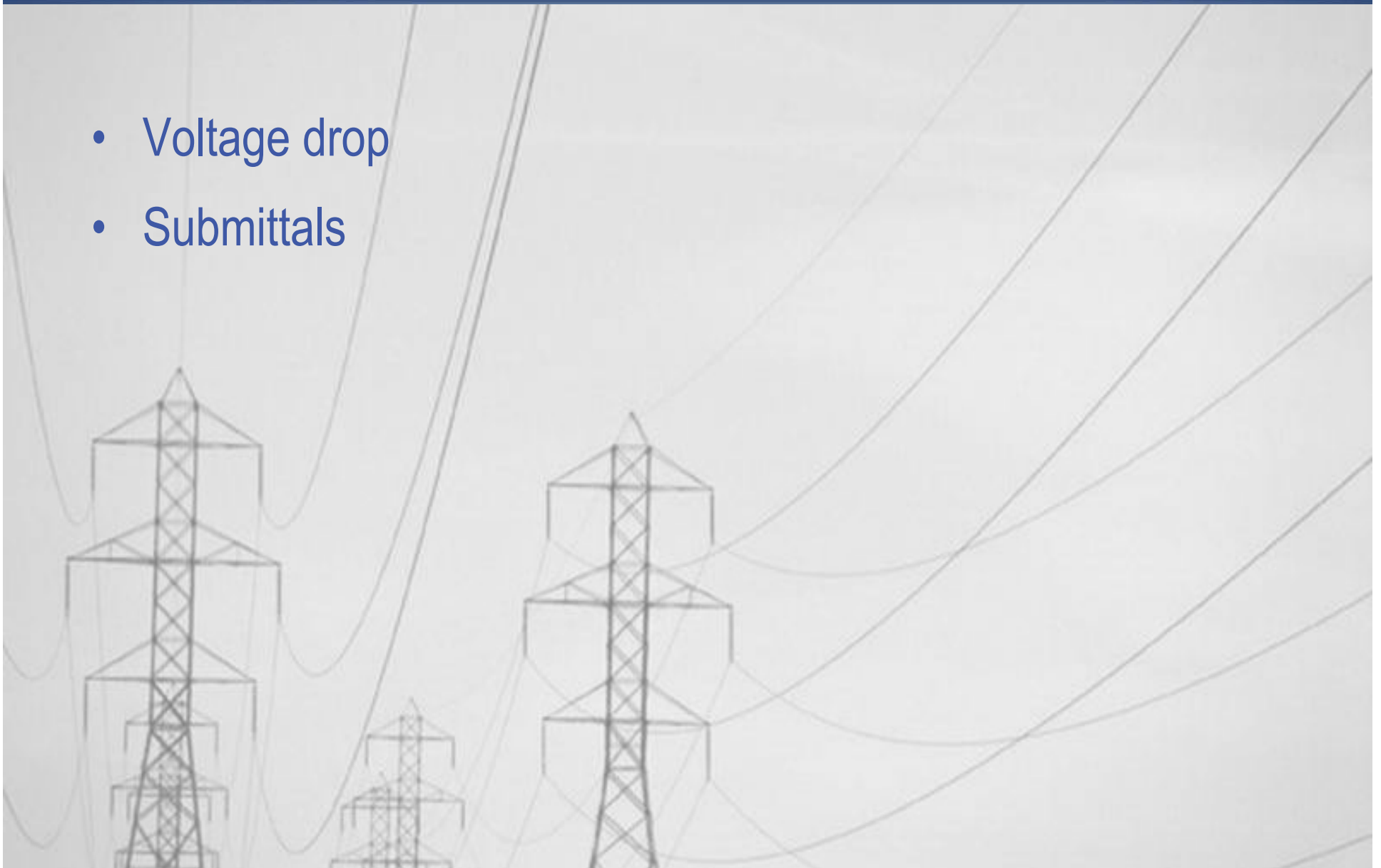
Energy Cost Budget

Simplified

## Energy Code Compliance

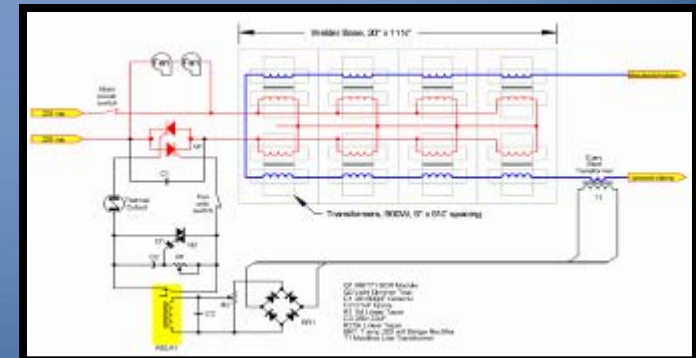
# ✓ Section 8 - Power

- Voltage drop
- Submittals



# Voltage Drop

- Two types of conductors
  - Feeder conductors
    - Connect service equipment to the branch circuit breaker panels
    - 2% maximum voltage drop allowed at design load
  - Branch circuit conductors
    - Run from the final circuit breaker to the outlet or load
    - 3% maximum voltage drop allowed at design load
- These are more stringent than non-enforceable requirements in the National Electric Code (NEC)

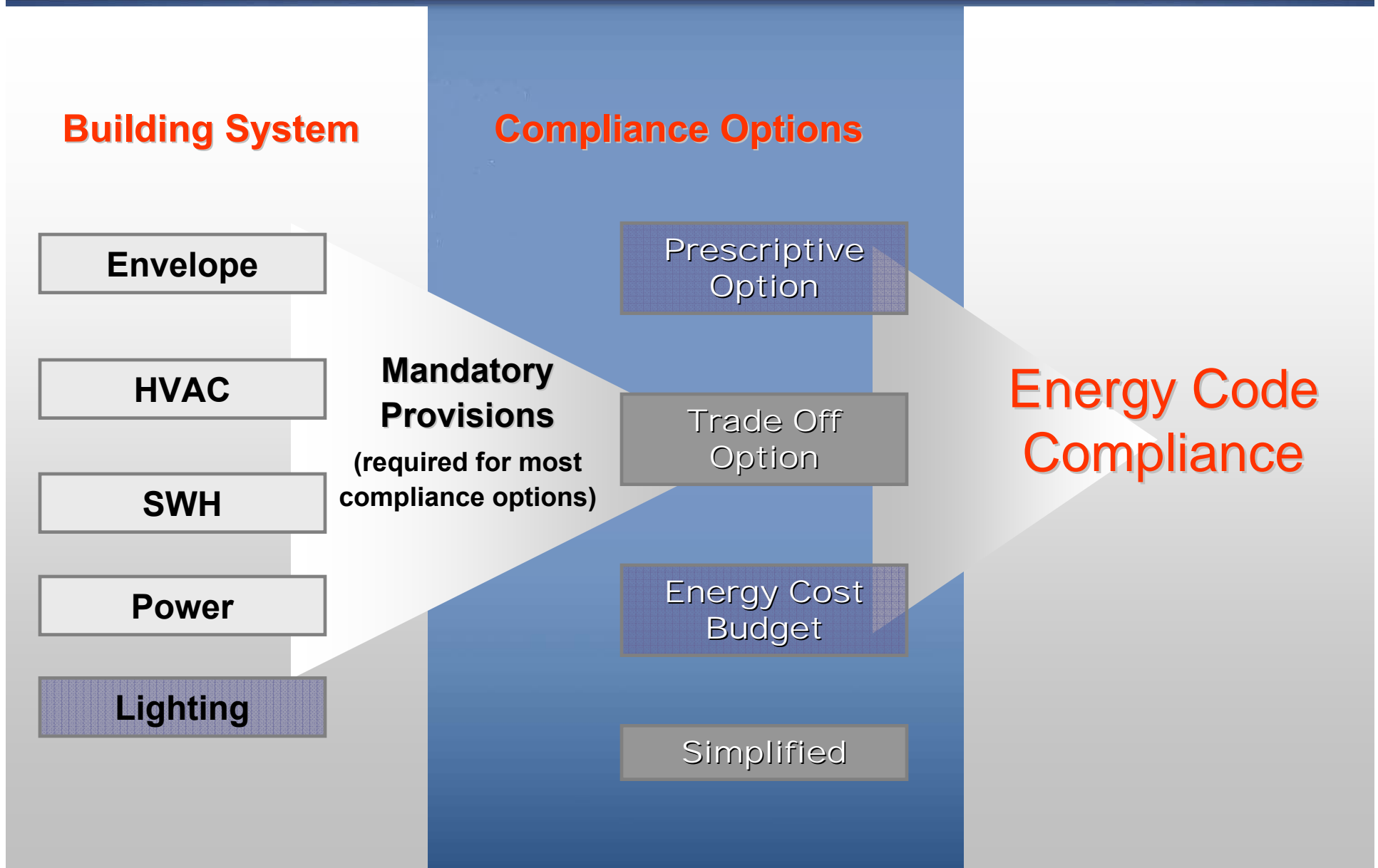


# ✓ Power Submittals

- Owner gets information about the building's electrical system
  - Record drawings of actual installation within 30 days
    - Single-line diagram of electrical distribution system
    - Floor plans showing location and areas served for all distribution
  - Manuals
    - Submittal data stating equipment rating
    - O&M manuals for equipment
    - Qualified service agency
    - Complete narrative of system as it's normally intended to operate



# ✓ Lighting Compliance





# ✓ Section 9 - Lighting

- General Application (*Section 9.1*)
  - Scope
  - Lighting Alterations
  - Installed Interior Lighting Power
  - Luminaire Wattage
- Compliance Path(s) (*Section 9.2*)
- Mandatory Provisions (*Section 9.4*)
  - Lighting control
  - Tandem wiring
  - Exit signs
  - Exterior building grounds lighting
  - Exterior building lighting power
- Building Area Method Compliance Path (*Section 9.5*)
- Alternative Compliance Path: Space-by-Space Method (*Section 9.6*)



# ✓ Lighting General

- Scope
  - Interior spaces of buildings
  - Exterior building features
  - Exterior grounds lighting powered through building
  - Exceptions
    - Emergency lighting
    - Lighting required by life safety statute
    - Lighting within dwelling units of buildings
    - Decorative gas lighting
- Lighting Alterations – New lighting and lighting controls must comply with this section, unless an alteration replaces less than 50% of luminaires in a space and that alteration does not increase the installed lighting power



# Lighting General

- Installed Interior Lighting Power shall include all power used by the luminaires, including lamps, ballasts, transformers, and controls
  - Exception: in the case where there are two independently operated lighting systems that are controlled to prevent simultaneous operation
    - Include only the higher wattage system
- Luminaire Wattage for various systems shall determined in accordance with details in Section 9.1.4

# Basic Lighting Requirements

**Mandatory Requirements (Interior and Exterior)**

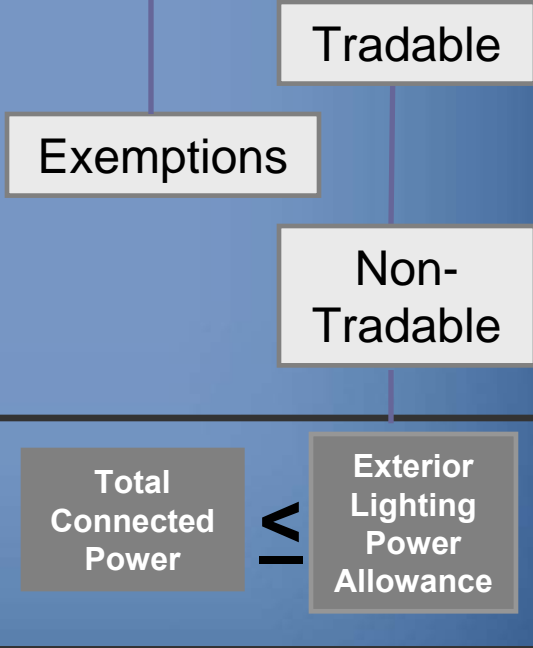
- Controls
- Switching
- Efficiency

**Interior Lighting Power Limits**

$$\text{Total Connected Power} \leq \text{Interior Lighting Power Allowance}$$

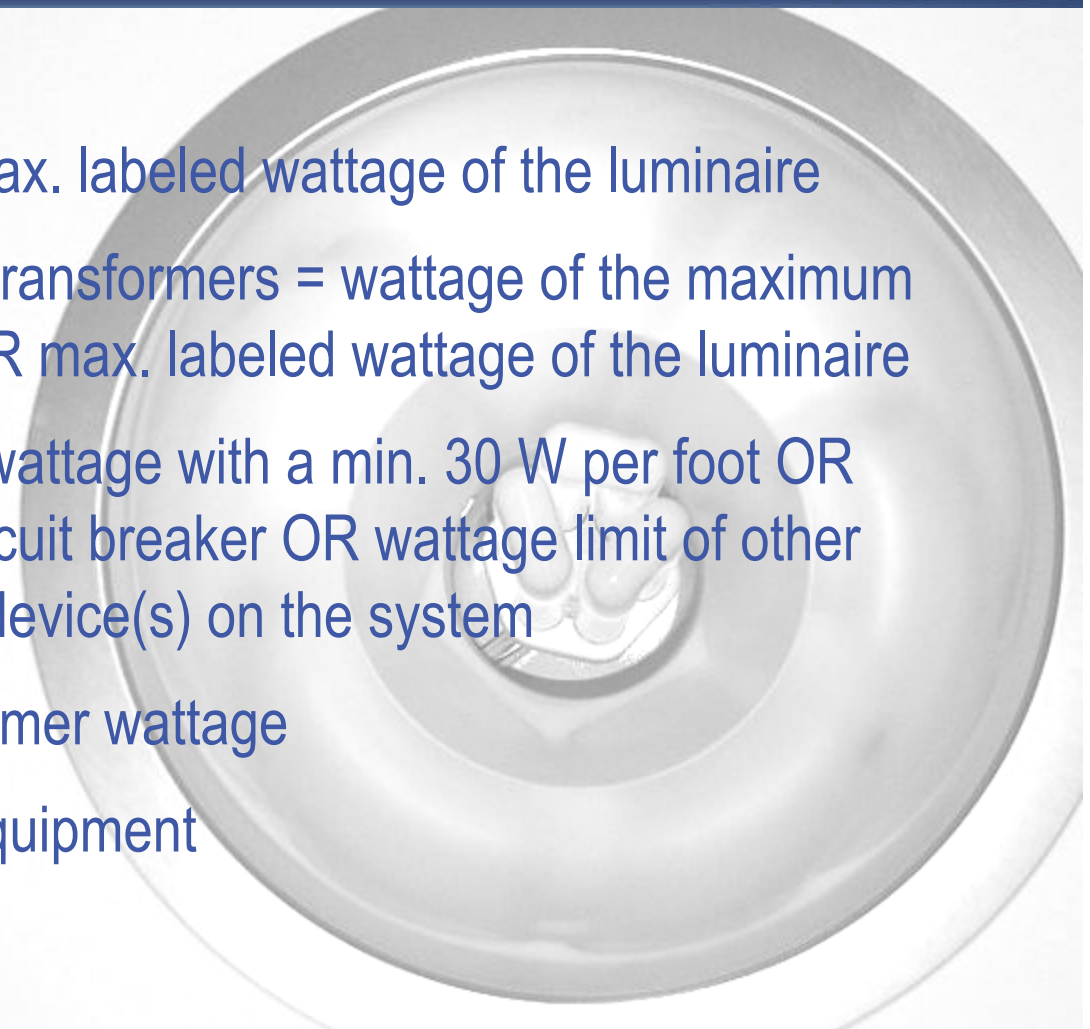
- Exemptions
- Whole Building  
OR  
Space-by-Space
- Additional Allowances

**Exterior Lighting Power Limits**



# ✓ Luminaire Wattage

- Standard incandescent = max. labeled wattage of the luminaire
- Luminaires with ballasts or transformers = wattage of the maximum lamp/ballast combination OR max. labeled wattage of the luminaire
- Line voltage track = actual wattage with a min. 30 W per foot OR wattage limit of system's circuit breaker OR wattage limit of other permanent-current-limiting device(s) on the system
- Low voltage track = transformer wattage
- All others as specified on equipment





# Mandatory: Individual Space Control

- At least one for each room or space enclosed by ceiling-height partitions
  - in spaces  $\leq 10,000$  ft<sup>2</sup>, each control serves 2500 ft<sup>2</sup> maximum and in spaces  $> 10,000$  ft<sup>2</sup>, serves 10,000 ft<sup>2</sup> maximum
- Readily accessible to occupants
- Remote location is allowed to accommodate areas where safety or security is a concern



# ✓ Mandatory: Additional Space Controls

- Hotel/motel guest room lighting must be controlled at room entry



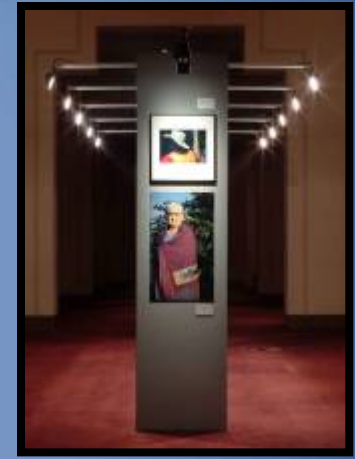
- Occupancy sensors are required in:
  - Classrooms (except shop, lab, K-12)
  - Conference/meeting rooms
  - Employee lunch/break rooms





# Mandatory: Individual Space Control

- Additional control required for:
  - Display/accent lighting
  - Case lighting
  - Task lighting
  - Nonvisual lighting
  - Demonstration lighting







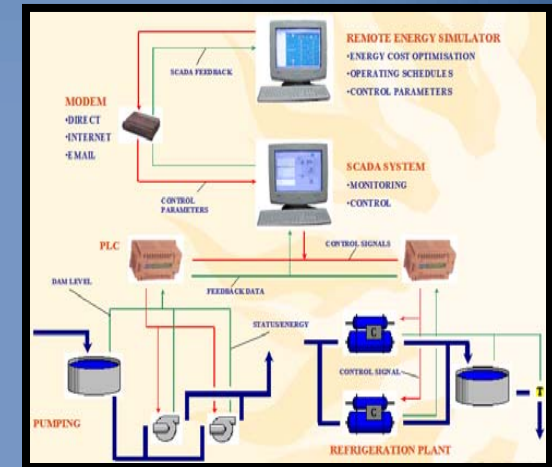
# Mandatory: Automatic Shutoff

- Automatic lighting shutoff control device required in all buildings larger than 5,000 ft<sup>2</sup>
- Override of automatic shutoff required for not more than 4 hours
- Exceptions to automatic shutoff:
  - Lighting for 24-hour operation
  - Patient care spaces
  - Areas with safety or security concerns



# ✓ Automatic Shutoff

- Compliance options:
- Control lights on a scheduled basis (automatic time switch)
  - Time-of-day controller
  - Controls  $\leq 25,000$  ft<sup>2</sup> and not more than one floor
- Occupant sensor
  - Turn lights off within 30 minutes of occupant leaving the space
- Signal from another control or alarm that indicates the area is unoccupied





# Application of Automatic Shutoff

Intent is to apply to business entities or structures where whole building control is practical

Example application:

- Strip mall – individual business unit



# ✓ Exterior Lighting Control

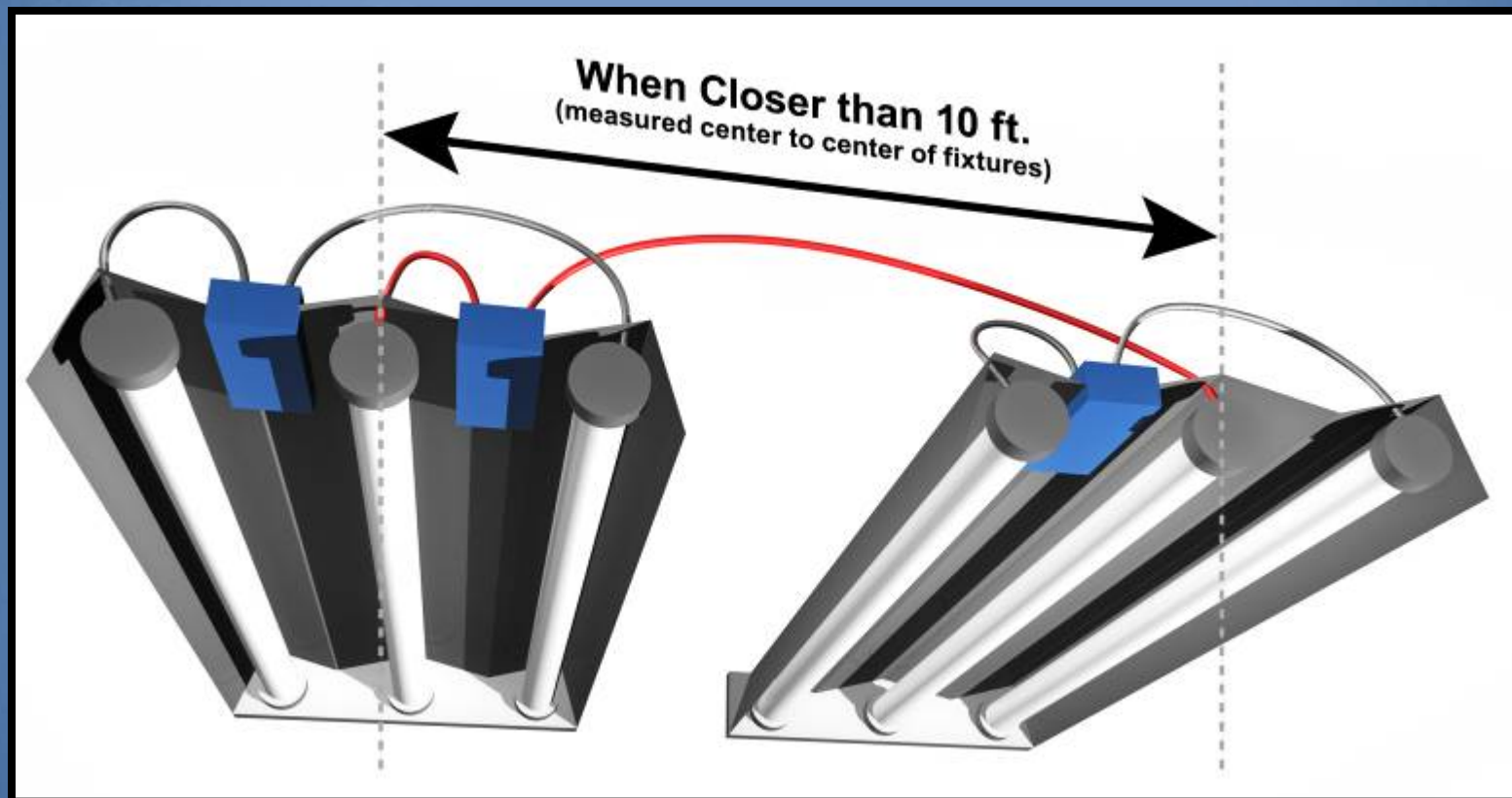
- For dusk-to-dawn lighting: astronomical time switch or photosensor
- For all other: astronomical time switch OR photosensor + time switch [REVISED!]
- All time switches must have 10 hour battery backup
- Exceptions:
  - Covered vehicle entrances
  - Exits from buildings or parking structures
  - (where required for safety, security, or eye adaptation)



# ✓ Additional Control

- Many special lighting applications must be controlled separately
  - Display/accent lighting
  - Case lighting
  - Hotel/motel guest room lighting
  - Task lighting
  - Nonvisual lighting
  - Demonstration lighting

# ✓ Tandem Wiring



Eliminate use of single lamp, low-frequency ballast where possible

# ✓ Tandem Wiring Exceptions

- Separated surface or pendant luminaires
- Recessed luminaires more than 10 ft apart
- Other luminaires
  - With three-lamp ballasts
  - On emergency lighting circuits
  - With no available pair
  - With one lamp, high frequency, electronic ballast



# ✓ Exit Signs

- Limited to 5 watts per face







# Exterior Lighting Power

- Building grounds lighting luminaires over 100 watts must have lamp efficacy of at least 60 lumen/Watt
- Exterior Building Lighting Power must meet prescribed wattage limits. Exterior applications divided into 2 categories:

**Tradable:** allowed wattage may be traded among these applications

**Non-Tradable:** allowed wattage cannot be traded between surfaces or with other exterior lighting

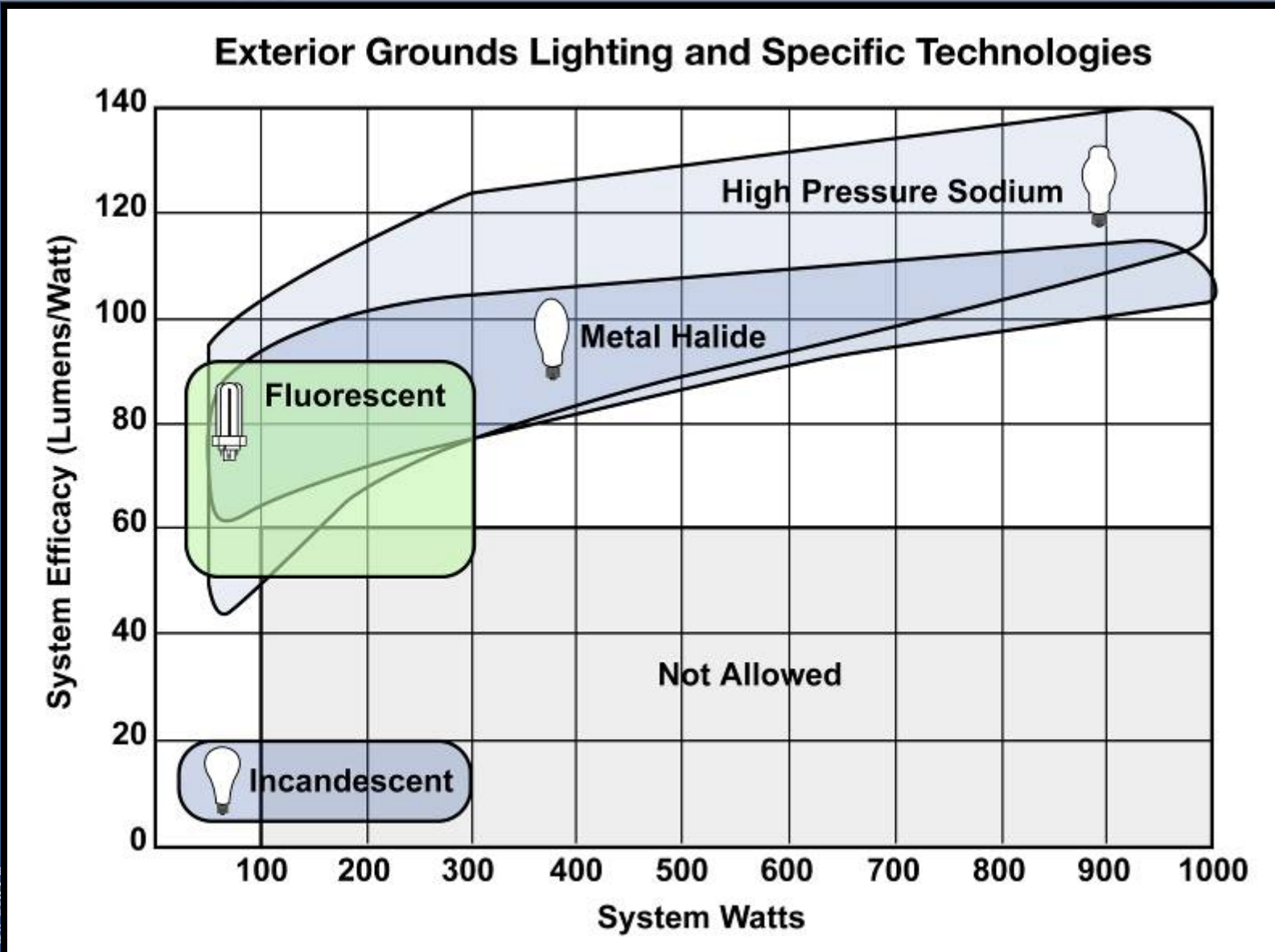


# Efficacy

- The ratio of light output to watts input
  - lumens per watt
- The higher the efficacy, the more efficient the light source
  - 40 watt incandescent = 480 lumens
  - 40 watt fluorescent = 2640 lumens



# Efficacy



# ✓ Exterior Building Lighting Power

- The total exterior lighting power allowance is the sum of the individual lighting power densities [LPD]....
- ....plus an additional unrestricted allowance of 5% of that sum. Trade-offs are allowed only among “Tradable Surfaces” applications.
- Some exemptions apply





# Exterior Building Lighting Power

- Lighting used for the following exterior applications is exempt when equipped with a control device independent of the control of the nonexempt lighting:
  - specialized signal, directional, and marker lighting associated with transportation;
  - lighting that is integral to advertising signage or directional signage;
  - lighting that is integral to equipment or instrumentation and is installed by its manufacturer;
  - lighting for theatrical purposes, including performance, stage, film, and video production;
  - lighting for athletic playing areas;
  - temporary lighting;
  - lighting for industrial production, material handling, transportation sites, and associated storage areas;
  - theme elements in theme/amusement parks;
  - lighting used to highlight features of public monuments and registered historic landmark structures or buildings.





# Exterior LPDs: 90.1-2007

Applications	Lighting Power Densities
<b>Tradable Surfaces</b> (Lighting Power Densities for open parking areas, building grounds, building entrances and exits, canopies and overhangs, and outdoor sales areas may be traded)	
<b>Uncovered Parking Areas</b>	
Parking lots and drives	0.15 W/ft <sup>2</sup>
<b>Building Grounds</b>	
Walkways less than 10 feet wide	1.0 W/linear foot
Walkways 10 feet wide or greater, Plaza areas and Special feature areas	0.2 W/ft <sup>2</sup>
Stairways	1.0 W/ft <sup>2</sup>



# Exterior LPDs: 90.1-2007

Applications	Lighting Power Densities
<b>More Tradable Surfaces...</b>	
<b>Building Entrances and Exits</b>	
Main entries	30 W/linear foot of door width
Other doors	20 W/linear foot of door width
<b>Canopies and Overhangs</b>	
Canopies (free standing & attached) and overhangs	1.25 W/ft <sup>2</sup>
<b>Outdoor Sales</b>	
Open areas (including vehicle sales lots)	0.5 W/ft <sup>2</sup>
Street frontage for vehicle sales lots in addition to "open area" allowance	20 W/linear foot





# Exterior LPDs: 90.1-2007

Applications	Lighting Power Densities
<p><b>Non-Tradable Surfaces</b> (Lighting Power Density calculations for the following applications can only be used for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the Tradable Surfaces section of this table.)</p>	
Building facades	0.2 W/ft <sup>2</sup> for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length
Automated teller machines & night depositories	270 W per location plus 90 watts per additional ATM per location
Entrances and gatehouse inspection stations at guarded facilities	1.25 W/ft <sup>2</sup> of uncovered area (covered areas are included in the Canopies and Overhangs section of Tradable Surfaces)





# Exterior LPDs: 90.1-2007

Applications	Lighting Power Densities
<b>Non-Tradable Surfaces</b>	
Loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.5 W/ft <sup>2</sup> of uncovered area (covered areas are included in the Canopies and Overhangs section of Tradable Surfaces)
Drive-up windows at fast food restaurants	400 W per drive through
Parking near 24-hour retail entrances	800 W per main entry

# ✓ Interior Lighting Power

- Lots of exemptions
- Calculation methods
  - Building area
  - Space-by-space
  - Trade-offs of interior lighting power allowance among portions of the building for which a different calculation method has been used is not permitted

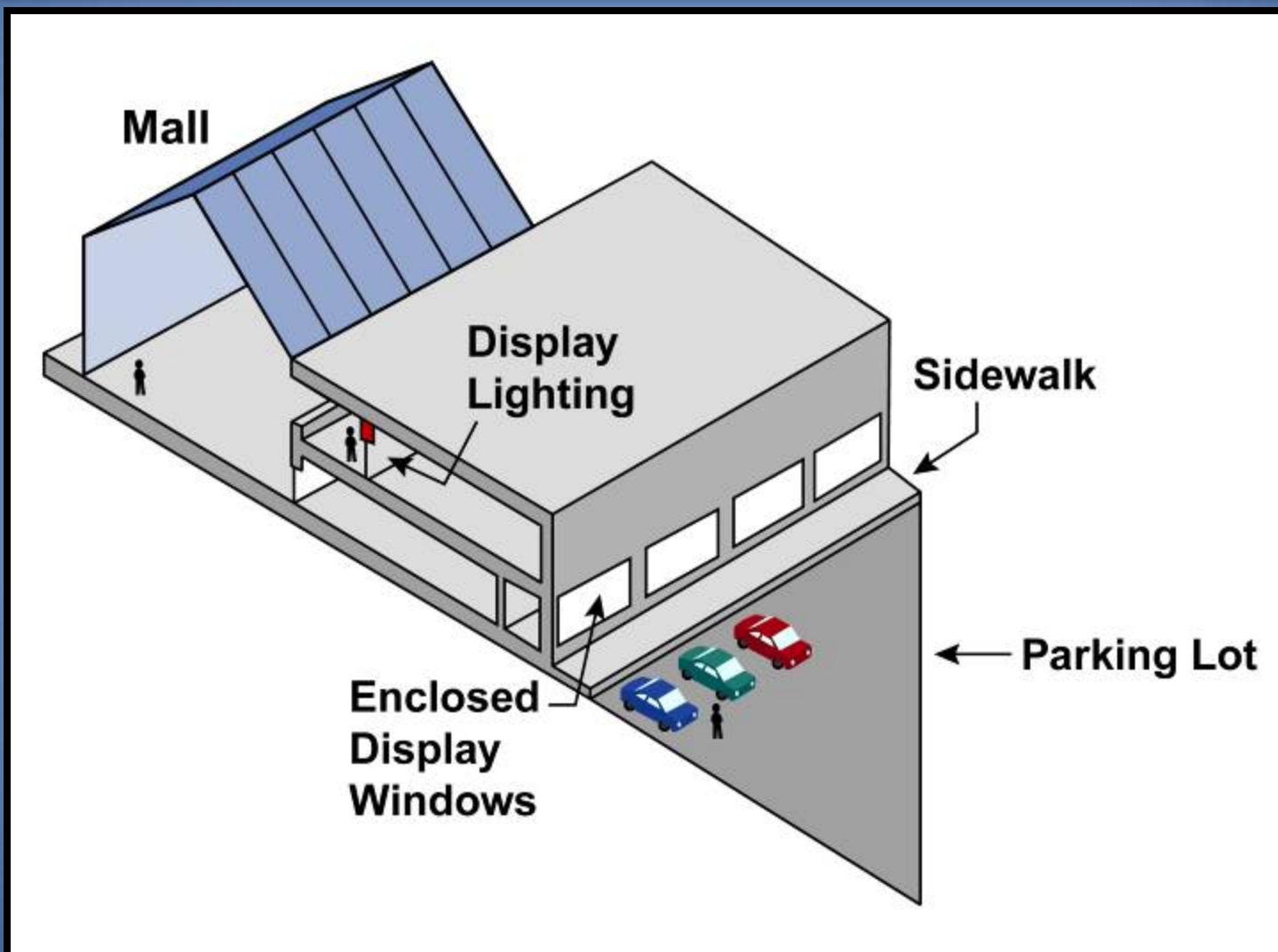


# ✓ Lighting Power Allowance Exemptions

- Theatrical, stage, film, and video production
- Medical and dental procedures
- Exhibit displays for museums, monuments, and galleries
- Plant growth or maintenance
- Integral to equipment or instrumentation installed by manufacturer
- Integral to both open and glass-enclosed refrigerator and freezer cases
- Retail display windows, provided the display is enclosed by ceiling-height partitions
- Food warming and food preparation equipment
- Interior spaces specifically designated as registered interior historic landmarks
- Integral part of advertising or directional signage
- Exit signs
- Sale or lighting educational demonstration systems
- Lighting for television broadcasting in sporting activity areas
- Casino gaming areas
- Furniture-mounted supplemental task lighting controlled by automatic shutoff and complying with 9.4.1.4(d)
- For use in areas specifically designed for occupants with special needs



# Exemption Example





# Building Area Method of Calculating Interior Lighting Power Allowance

- Used for projects involving
  - An entire building
  - A single, independent, and separate occupancy in a multi-occupancy building
- Gross lighted area is multiplied by allowance from Table 9.5.1
- Limitations
  - Insensitive to specific space functions and room configurations
  - Generally is more restrictive
  - Does not apply to all building types - but “selection of a reasonably equivalent type” is permitted



# ✓ Gross Lighted Area

- Sum of total lighted area of a building
  - Measured from the exterior faces of the exterior walls or from the centerline of walls separating buildings, but excluding a long list of areas. (See Standard).
- Used in the building area method of determining interior lighting power allowance



# ✓ Building Area Allowances

- Table 9.5.1

Building Type	Lighting Power Density (W/ft <sup>2</sup> )
Automotive Facility	0.9
Convention Center	1.2
Court House	1.2
Dining: Bar Lounge/Leisure	1.3
Dining: Cafeteria/Fast Food	1.4
Dining: Family	1.6
Dormitory	1.0
Exercise Center	1.0
•	•
•	•
•	•



# Space-by-Space Method of Calculating Interior Lighting Power Allowance

- Identify different building types in your project
- Divide gross lighted area of the building into each of the space types
- Calculate lighting power allowance by multiplying area of space type by lighting power density for that specific space type
- Sum all the allowances
- Advantages
  - More flexible
  - Applicable to all building types
  - Accounts for room geometry (e.g., lighting needs of enclosed office vs. open office)





# ✓ Additional Interior Lighting Power

- An increase in the ILPA is allowed for specific space functions when using the space-by-space method. Applications must be automatically controlled, separately from the general lighting, to be turned off during non-business hours
  - Decorative in addition to general lighting –  $1.0 \text{ W/ft}^2$  in space used
  - Fluorescent designed to eliminate computer screen glare –  $0.35 \text{ W/ft}^2$
  - Retail display lighting





# Retail Display Lighting

Additional Interior Lighting Power Allowance = 1000 watts +  
(Retail Area 1 x 1.0 W/ft<sup>2</sup>) +  
(Retail Area 2 x 1.7 W/ft<sup>2</sup>) +  
(Retail Area 3 x 2.6 W/ft<sup>2</sup>) +  
(Retail Area 4 x 4.2 W/ft<sup>2</sup>),

Where:

**Retail Area 1** = the floor area for all products not listed in Retail Area 2, 3 or 4.

**Retail Area 2** = the floor area used for the sale of vehicles, sporting goods and small electronics.

**Retail Area 3** = the floor area used for the sale of furniture, clothing, cosmetics and artwork.

**Retail Area 4** = the floor area used for the sale of jewelry, crystal, and china.

Exception: Other merchandise categories may be included in Retail Areas 2 through 4 above, provided that justification documenting the need for additional lighting power based on visual inspection, contrast, or other critical display is approved by the authority having jurisdiction.

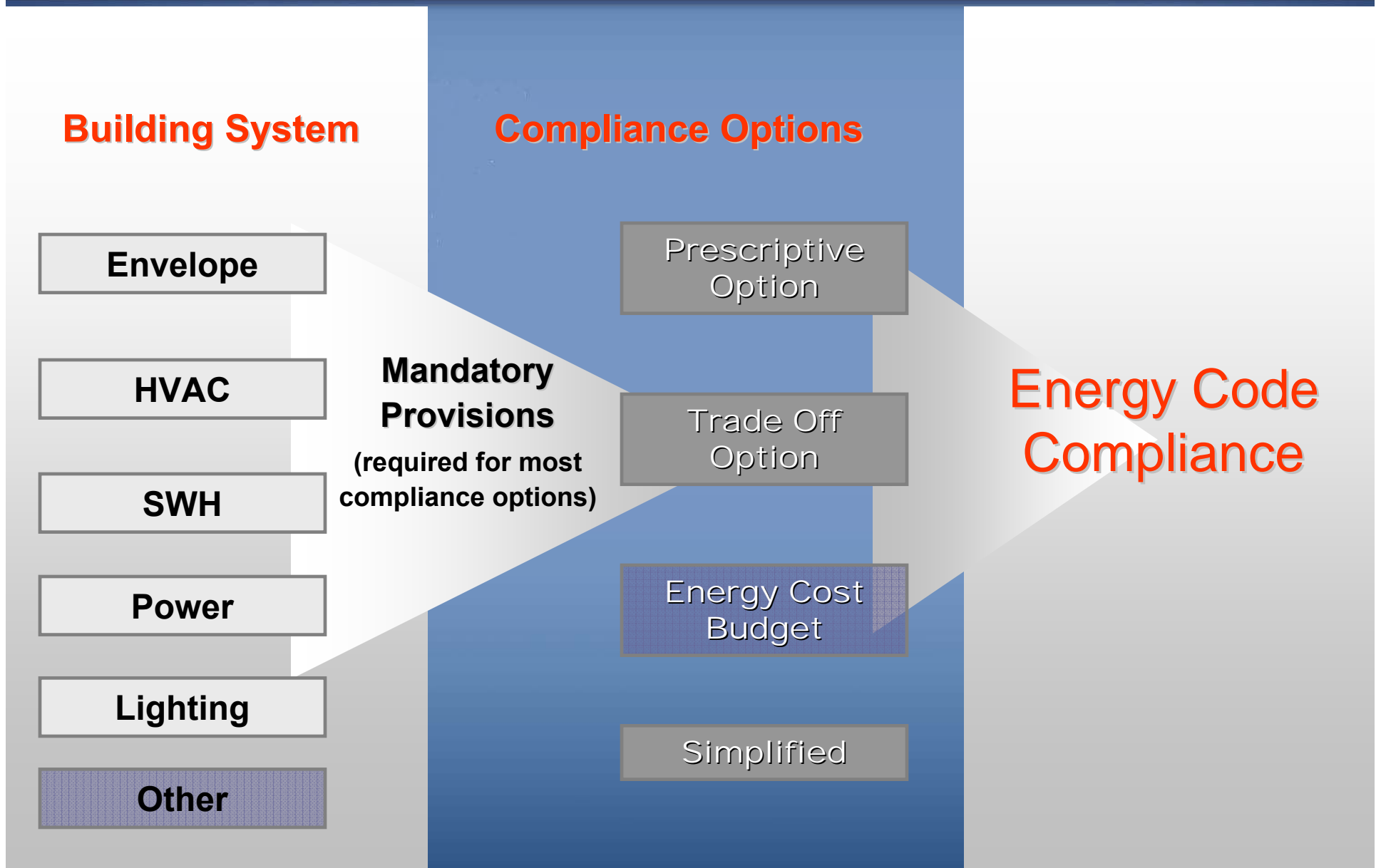


# Submittals

- There are no submittals associated with the lighting requirements



# ✓ Other Compliance



# ✓ Section 10 - Other Equipment

- Motor efficiency levels correspond to Energy Policy Act of 1992 manufacturing standards
- Mandatory provisions are for General Purpose Design A and Design B motors only
- Motors in new buildings, additions to existing buildings, and alterations to existing buildings must comply
  - Relocated or reused existing motors do not have to meet these requirements
- No small building option, no prescriptive compliance path, no alternative compliance paths, no submittals

# ✓ Section 11 - Energy Cost Budget Method

- The ultimate trade-off method allowing you to trade-off across building systems through the use of annual, hourly simulation tools and a baseline building
- The only real way to deal with unique designs, renewables, high-efficiency equipment, etc.
- The basis of the energy portion of the LEED rating
- Limits allowable energy costs of the design to those of a building meeting the Standard
- Buildings must still meet all mandatory requirements (Section X.4)





## Section 11 - Energy Cost Budget Method

- Tradeoff limited to building permit
- You have to have an approved building envelope design prior to ECB submittal
- You must meet all the X.4 sections AND the design energy cost cannot exceed the energy cost budget AND the energy efficiency level of components must meet or exceed the levels used to calculate the design energy cost
- You must document all this in great detail





## Section 11 - Energy Cost Budget Method

- Use a good and approved simulation program
- Use appropriate and approved climate data
- Use appropriate and approved purchased energy rates
- Use the same simulation program, climate data, and purchased energy rates for both the design energy cost and energy cost budget
- Get approval to deal with exceptional calculations that aren't covered in the simulation program







## Section 11 - Energy Cost Budget Method

- Develop your proposed building design and budget building design in accordance with Table 11.3.1
  - This table “locks down” a number of building design parameters
- Choose your budget building HVAC system from Figure 11.3.2 and Table 11.3.2A





## Section 11 - Energy Cost Budget Method

- If you are attempting to show that your building goes “above code” (say, for instance, for LEED energy points) as opposed to simply using ECB as a very flexible and complex code compliance tradeoff option,
  - be sure to see Informative Appendix G, which contains many of the same elements as Section 11, but with modifications to accommodate the needs of “above code” programs



# ✓ Section 12 - Normative References

- Normative (read “mandatory”) reference documents
- Includes test methods, rating procedures, and other standards



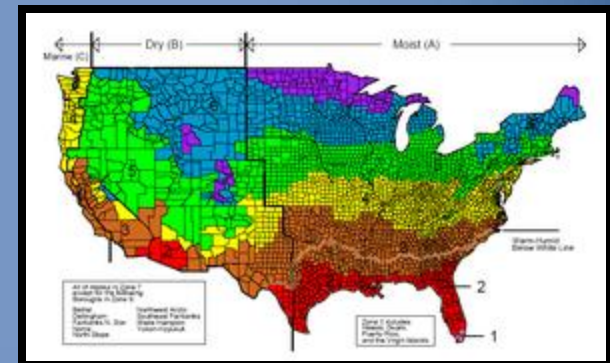
# ✓ Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations

- Includes pre-calculated U-factors, C-factors, and F-factors
  - Above-grade walls
  - Below-grade walls
  - Floors
  - Slab-on-grade floors
  - Opaque doors
  - Fenestration



# ✓ Building Envelope Climate Criteria

- Defines which of the envelope criteria tables (Tables 5.5-X) to use for your location
- General
  - Climate Zone Map
  - U.S. Climate Zones (by County)
  - Canadian Climatic Zones (by City)
  - International Climate Zone (by City)
- Major Climate Type Definitions (for use with non-U.S. locations)



# ✓ Methodology for Building Envelope Trade-Off Option in Subsection 5.6

- The details of how the envelope trade-off option referenced in Section 5.6 is implemented
- This methodology is implemented in the ENVSTD software distributed with the 90.1 Users Manual





# Climate Data

- Climatic data for a number of US, Canadian, and international locations
  - HDD65 and CDD50
  - Heating and cooling design temperatures
  - “number of hours between 8 am and 4 pm with Tdb between 55 and 69”
- Used exclusively for HVAC calculations





# Informative References

- Other useful references that are not mandatory, but are useful as examples for the user of Standard 90.1-2007
- In general, these are not consensus documents so ASHRAE procedures do not allow them to be mandatory references







# Addenda Description Information

- Information on addenda to ANSI/ASHRAE/IESNA Standard 90.1-2004 (the predecessor to Standard 90.1-2007)
- ASHRAE issued 44 addenda to Standard 90.1-2004
- Standard 90.1-2004 plus these addenda forms the basis of Standard 90.1-2007



# ✓ Performance Rating Method

- Instructions for using the ANSI/ASHRAE/IESNA Standard 90.1-2007 Energy Cost Budget Method in conjunction with the U.S. Green Buildings Council (USGBC) Leadership in Energy and Environmental Design (LEED) program

